RISK IDENTIFICATION IN MAJOR WEAPON SYSTEMS ACQUISITION IN THE REPUBLIC OF CHINA AIR FORCE

THESIS

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Preface

Two things motivated me to embark upon this research. The first was a strong sense of responsibility to use what I have learned from the AFIT to assist my country and the ROCAF with risk identification. The second reason for this research and thesis was to complete the obvious requirements for a Master of Science degree at the AFIT.

In writing this thesis I had a great deal of help from others. I first want to thank Major Edward J. Berghorn, the section leader of GSM92, for his friendship and for being with me through this rigorous program.

I especially want to thank my wife, Shou-hua, and my daughters, Yi-ting and Hsing-chieh, for their patience and support during this very trying period.

I also want to offer my sincere gratitude to my advisor, Major Kevin P. Grant, PhD, an outstanding instructor and USAF officer. His guidance and support encouraged me and gave me the confidence to persevere through the many long hours of academic study and to reach "the pleasantness of bell-knocking".

Finally, but not necessarily the least, I want to thank Professor Daniel Reynolds, one of the best instructors in the AFIT who motivated me to appreciate the wonderful domain of statistics, and help me personally as well. Thank you, Dan.

Te-lung Tsai

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Abstract

This research examined the magnitudes of the performance, supportability, life-cycle cost, schedule, and management risk factors in current Republic of China Air Force (ROCAF) weapon systems acquisition programs and analyzed the risk drivers with respect to those risk factors.

Mid-to-high level managers in the ROCAF and Chung-Sun Institute of Science and Technology (CSIST) were surveyed to determine the extent to which various risk factors were contributing to program risk. A total of fifty-four (54) managers responded to the survey. The results revealed high risks associated with performance, supportability, life cycle cost, and schedule, and moderate risk associated with management. Two major drivers of high risk in multiple risk factors were also identified. First, ambiguous requirements or frequent requirements changes drive performance, cost, and schedule risks. Second, tight program schedules caused by the need for rapid system deployment contribute to performance and supportability risks. Finally, recommendations for mitigating those risks and for future studies were also made.

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I. Introduction

Background

In 1982 the Reagan administration enacted the 817 Communique stipulating the sale of military equipment to the Republic of China (ROC) on a yearly diminution basis (14:74). In addition, the communist People's Republic of China (PRC) has always sought to obstruct the purchase of defensive weapons by the ROC. For these reasons, independent weapon systems development for national defense was begun in the ROC in early 1980.

The goal was to develop major defensive systems for the armed forces independent of other nations. The government authorized the Chung-Sun Institute of Science and Technology (CSIST), a governmental aeronautic and scientific research-and-development organization, to lead pursuit of the goal by initiating development of the first ROC jet fighter--the Indigenous Defense Fighter (IDF). The IDF is expected to replace the aging fleet of ROC Air Force (ROCAF) aircraft. Ultimately the ROCAF seeks to develop acquisition experience and to satisfy the operational user of the IDF--the ROCAF.

In addition, the government wanted to shorten the acquisition process so that systems could be deployed as soon as possible. This would help alleviate the expansion of the force gap in the Taiwan Strait between the ROC and PRC and eventually result in a regional strategic military balance. This balance would allow the ROC to pursue continued economic growth as well as constructive and peaceful political dialogue across the Strait (15:39).

Successful systems development requires an educated and experienced work force as well as modern facilities and an appropriate budget. However, it's unlikely that resources will be unlimited. In fact, it's more likely that a system will have at least one constraint which impedes the system from achieving a goal of higher performance (1:4).

Problem Statement

Constraints. Based on years of involvement with the IDF program, the researcher has personally experienced several constraints (barriers) to weapon systems acquisition in the ROCAF. These constraints have increased the complexity of the program and resulted in program risks that are higher than usual. There is, however, much the government can do to reduce the impacts. In short, the constraints can be categorized as follows:

A. A majority of the managers and engineers in both the ROCAF and CSIST lack relevant experience.

B. Few people are familiar with the entire acquisition process and the pitfalls.

C. In many cases, an acquisition strategy of compressed acquisition phases would be necessary to meet the requirement for faster systems deployment. Concurrency will be inevitable and will, very possibly, introduce additional complexities to program management.

D. There is a shortage of personnel to conduct program management.

<u>Risk</u>. With the IDF program the ROCAF has already gained extensive experience in systems development. But, nonetheless, an advanced training program would ensure that both management and staff gain the appropriate knowledge necessary to mitigate program risk. To alleviate program risk, the risks themselves, their impacts, and constructive solutions must be identified. The risks include:

A. High system costs.

B. Unsatisfactory system performance and/or supportability.

C. Frequent engineering changes during development and testing phases which could cause schedule slippage and budget overrun.

When these phenomena occur, the goal of early systems deployment or success of the programs themselves may be in jeopardy. In short, however, in accord with the policy of pursuing independence of national defense, the ROCAF will continue its weapon systems development in spite of the many inherent risks (34:61).

Sole-Source Policy

A ROCAF policy which might be deemed as a problem, one that differs from the United States Air Force (USAF) and the Department of Defense (DoD) acquisition policy, is the selection of a sole-source prime contractor in the ROCAF versus competitively selecting a source as in the U.S. in accordance with the U.S. Competition in Contracting Act (CICA) passed in 1984. According to DoDD 5000.1, the CICA which was enacted to help reduce the budget deficit during the Reagan administration (21:1), stresses that "Defense systems, subsystems, equipment, supplies and services shall be acquired on a competitive basis to the maximum extent practicable as a means of achieving cost, schedule, and performance benefits" (19:1-6).

For the ROCAF, the reliance upon a single contractor (CSIST) for a major program development may not constitute a high risk because of the existence of acquisition strategies, different from those used in the U.S., for achieving program objectives. One of the current ROCAF policies is to deploy systems as soon as possible; whereas the DoDD 5000.1 states that "schedule shall be subject to trade-off as a means of keeping risk at acceptable levels"

(19:1-5). Also there is a lack of evidence to prove exactly when ineffectiveness and inefficiency of any particular program should be attributed to the sole-source environment.

In addition, when considering technological innovation, section 2723 of the Competition in Contracting Act says an "agency head may exclude a particular source upon a determination that it would be in the interest of national defense in establishing or maintaining an essential engineering, research or development capability provided by an educational or other nonprofit institution, or federally funded research and development center" (21:60). This statement implies that the cheapest alternative is not always the best alternative. Furthermore, the apparent quantitative and qualitative advantages attained through competition and source selection; according to General Bernard P. Randolph, Commander, US Air Force Systems Command (7:18); are not necessarily hard to achieve in a single source environment. Stronger warranties, an expanded industrial base, technological innovation, better prices and larger quantities can also be realized if better management and cooperation in all phases of the acquisition process can be achieved. In addition, competition does not guarantee those advantages stated above if program management is not conducted intensively and responsibly. On the other hand, relying on single sources for essential items could, in fact, reduce future competition by reducing the industrial base which gives single-source producers limited incentives to reduce costs or invest profits in improved manufacturing or product technologies (8:50).

In the ROCAF, the sole-source contractor is a government-owned, non-profit institution (the CSIST), and there is no evidence to suggest that limited incentives have resulted in higher costs for this kind of institution. Nevertheless, through statistical analysis, this research will also determine whether a government-owned single-source enterprise has any incentives for reducing cost. Regardless, intensive management and production controls should be mandatory to overcome possible pitfalls in the ROCAF acquisition process.

Justification of Research

There are several reasons for doing this research: First, "Program risks and risk management plans shall be explicitly assessed at each milestone decision point prior to granting approval to proceed into the next acquisition phase" (19:1-4). In addition, "Critical parameters that are design cost drivers or have a significant impact on readiness, capability, or life cycle costs must be identified early and managed intensively" (19:1-4). From these two points addressed in DoDD 5000.1, it is obvious that assessing the program risks and identifying the risk drivers in advance of the program phases are beneficial to program success.

Second, defense systems acquisition is too expensive to learn every managerial lesson by trial-and-error. Acquisition experience is an intangible asset. However, field studies and/or investigations will yield many valuable lessons to assist the program manager. More specifically, the ROCAF (or the services), the CSIST, and the Ministry of National Defense (MND) will be able to adequately address the major risk areas as well as the causative factors ahead of, or during the program.

Third, "one indirect benefit that is a significant by-product of a detailed risk assessment is the improvement of program definition....Not only is program definition improved but all members of the program team develop improved understandings of the total program and their places within it" (17:III-4). Because the ROCAF and CSIST have different goals, organizational conflicts often impede the progress of a weapon system acquisition program. Although the unification of risk management theories aren't necessarily prerequisite to successful program management, a common understanding of acquisition management between the ROCAF and CSIST would result in better risk-management for the current and follow-on programs. However, the conflicts that occur between organizations and individuals during program management can be reduced by conducting problem-solving sessions to identify conflict causes. Contemporary managers use conflict to improve group cohesion and increase project performance (18:213).

Fourth, the process of defense acquisition covers a long period of time. It would be cost and schedule prohibitive for both tax-payers and the user to have a program terminate for default after funds are obligated and the acquisition and development has proceeded. Because penalizing the program manager won't recover the loss, program management demands adequately trained personnel to insure the selected source can do the work. This is especially true for a country with limited resources and a defensive policy as a national strategy like the Republic of China. For program management to be successful, one must understand the characteristics of the programs as well as the risks and their drivers in advance.

Fifth, the findings and recommendations resulting from this research could be applied to the systems development conducted by both the Republic of China Army and Navy as well as the ROCAF.

Research Objective

Risk Management Concepts and Guidance addresses five facets of risk that are necessary to segment and manage the cost, schedule, and performance issues of a project:

. Technical-(performance related)

. Supportability-(performance related)

. Programmatic-(management related)

. Cost.

. Schedule (6:3-3).

Cost and schedule risks are treated somewhat differently than the other three risk categories in that they are primarily indicators of project status. However, if they are not properly managed, cost overrun and schedule slippage can become major sources of program risk, and ultimately lead to program failure (6:3-3). The five facets together help define the research scope and the twofold purpose of this research:

A. To explore the magnitude of potential major risks in terms of performance, supportability, life-cycle cost, schedule, and management in the ROCAF's major systems acquisition process.

B. To know and understand the risk-drivers associated with each risk factor in weapon systems acquisition in the ROCAF.

Investigative Questions

The following questions will be examined and answered in order to achieve the objectives of this study.

Question 1. What is the magnitude of performance risk in systems acquisition? What causes the risk?

Question 2. What is the magnitude of supportability risk in systems acquisition? What causes the risk?

Question 3. What is the magnitude of life-cycle cost risk in systems acquisition? What causes the risk?

Question 4. What is the magnitude of schedule risk in systems acquisition? What causes the risk?

Question 5. What is the magnitude of management risk in systems acquisition? What causes the risk?

Summary

The independent defense systems development program supported by the ROC government provides technology for local industries, jobs for the populace, and defense for the country. Although the ROCAF may have additional reasons for the independent development of major weapon systems, the purpose of this study is to focus on identifying the risks in the current acquisition process. This chapter has briefly addressed the background of weapon systems development in the ROCAF, the problem statements, the research objectives, and the investigative questions which support this research. Chapter II will address a review of the literature concerning risk and risk management. Chapter III discusses the methodology used to execute this research. Chapter IV will examine the data and findings from this research, and Chapter V will provide the conclusions and recommendations.

II. Literature Review

Overview

Risk is the essence of economic activity. People consider risks everyday, whether in their personal lives, their businesses. Risk management is a disciplined, comprehensive and continuous management process in which the applicable tools and techniques are used to identify, evaluate and control the possibility of failure. Risk management is dependent on individual perceptions as well as the subjective and objective environments. These environments, in turn, generate unique acquisition strategies.

No matter how different the acquisition strategies might be, inevitably, there is some degree of risk in every program from "cradle to grave" due to uncertainties. Those risks, depending on the potential severity to the programs, may result in unwanted consequences, e.g., termination of a program for default. Termination not only wastes any previous investment but will result in a great deal of dissatisfaction for the end user as well as frustration and possible unemployment for those involved in the program. Although the concept of risk has been widely studied and documented, there is a general feeling that additional knowledge in the areas of risk and risk assessment would be useful to help assure satisfactory program completion (4:75). Therefore, the researcher, will review the general definition of risk in weapon systems acquisition; and then discuss the types of risk that exist in defense programs. In addition, the causes of program risk, risk management techniques (including those for risk identification), the psychology of risk, and the concept of risk quantification will be covered. Finally, risk cannot be 100% eliminated; therefore, the remaining risk is considered "acceptable risk" and must be adequately managed. This chapter will discuss acceptable risk and the part it plays in systems acquisition and contractor performance.

Review of Literature

Even though major weapon systems development in the ROC has matured over the past twelve years, there is very little previous research associated with program risk identification and management. A search of several business periodical indices, publications, and Air Force Institute of Technology theses revealed that research of defense weapons program risk as it applies to the Republic of China has not been accomplished.

Definition of Risk

Any job can be accomplished if there are no constraints such as time, budget, and manpower. Unfortunately, any real system will likely have at least one constraint (1:4). In fact, to conquer the challenges in the world without constraints is meaningless. Because of constraints, and associated risks, the advancement of technology has been furthered and we have been forced to develop solutions for managing those risks. With risk management as a normal part of systems acquisition, constraints that were previously devastating appear to be of little threat now. Does that suggest constraints are gone? The answer is no-for two reasons.

The first reason is the theory of greater demand, which states that customers will continually have higher expectations and competitors will continually pressure the status quo. Second, technological advancement calls for increased competence in modern management. This is definitely true in the weapon systems acquisition process-one of the most expensive programs that a country may have. For example, in the modern Electronic Warfare (EW) realm, Electronic Support Measures (ESM) are used to identify and locate the enemy's fire-control and guidance systems. By virtue of ESM, the enhancement of the probability of mission success as well as minimizing the loss of resources, e.g., equipment and lives, can be achieved. However, the effectiveness of the ESM could be reduced or defeated by the enemy's Electronic Counter Measures (ECM) techniques. ECM may also be minimized by advanced Electronic Counter-Counter Measures (ECCM).

Conceivably, in order to fulfill the greater requirements for national defense, a majority of weapon acquisitions are dealing with advanced technologies-technologies with risks that impede the program's ability to achieve desirable or planned goals. Therefore, a high degree of managerial skill is required for risk management in defense acquisition, and technical competence is extremely important as well (23:141). In addition, the constraints, whether subjective, objective or both, present many challenges that can keep programs from being a success. Knowing the nature of weapon systems development, it would be unthinkable to manage programs by simply hoping risks will take care of themselves. It would also be unthinkable to expect any resulting systems to be successfully developed, produced, and deployed with satisfactory quality and within budget.

According to Harold J. Schutt, Associate Dean, at the Defense Systems Management College (DSMC), "Program management is risk management or, in other words, the program manager's job is to manage risk." As a program manager, before any actions can be taken to adequately reduce the risks, risk should be conceptually understood in terms of the weapon systems acquisition process. What is risk? Webster's Dictionary defines it in generic terms as:

> **The possibility of loss, injury, disadvantage, or destruction: Contingency, Danger, Peril, Threat, etc (3:1963).**

Obviously, this definition does not explicitly pinpoint the situation that a program manager faces. DoDD 5000.2 defines risk in much more detail:

> **A subjective assessment made regarding the likelihood or probability of not achieving a specific objective by the time established with the resources provided or requested (2:15-15).**

Interestingly, there are a few key words in the definition which need further explanation for a better understanding of risk in terms of acquisition. These are, subjective assessment, specific objective, and resources provided.

A. Subjective Assessment. Because program managers have different propensities for taking risks, i.e., risk prone, risk neutral, and risk averse; the degree of risk sought by two different program managers might be dramatically different even in similar programs. Furthermore, "gut feel" risk assessments are often performed by program managers. In fact, one study showed that many Aeronautical Systems Division (ASD) program managers tended to perform qualitative risk assessments rather than quantitative risk assessments (4:77). (Note: ASD became the Aeronautical Systems Center on 1 July 1992). Moreover, there is no evidence to indicate that any standardized risk assessment methods were in existence at ASD (4:79).

The discrete judgments made by the program managers drive the program to success or failure. Support for such a statement may be found in the termination of the A-12 program for the U.S. Navy. The program was terminated for poor performance in 1991. In this case, the program manager viewed the problems surfaced by his line managers as normal and self correcting. He did not perceive the need to focus special attention on the problems (20:23-4). Unfortunately the problems caused excessive cost overruns and unacceptable schedule slippage.

Quantitative risk analysis might have helped the A-12 program. However, quantitative analysis of risk alone forgoes the opportunity to infuse intuition to help decision making if there is a high level of uncertainty, little precedent, limited time, or too many plausible alternatives (22:49). Further, the investigation done in 1989 showed that under the current ASD management climate, the majority of mid-to-high level ASD managers did not have the time necessary for performing more extensive risk assessment (4:77). Clearly, subjective assessments are integral to the risk identification process.

B. Specific Objective. A general objective of weapon systems acquisition can be found in the DoDD 5000.1.

> **An integrated management framework shall be used for translating broadly stated mission needs into stable, affordable acquisition programs that meet the user's needs and can be sustained given project resource constraints (19:1-1).**

Even though specific objectives vary from program to program, in most defense acquisition programs, the objectives essentially focus on fulfilling the specified requirements on time and within the budget.

The same is true in the ROCAF. The objective is to satisfy the customers and the Legislative Yuan (the ROC Congress). Quite frequently, defense program management requires decision-making and trade-offs in cost, schedule, and performance. The judgmental skills necessary to determine acceptable level of risk will be discussed later in this chapter. In addition, there is a trap that one should avoid when dealing with specific program objectives. The problem is that many people assess good program management on the basis of cost and schedule alone because of the difficulty in evaluating the performance until after prototype development. This trap must be avoided.

C. Resources Provided. As stated previously, there are normally limited resources provided for a program. A program manager will always encounter some constraints. The most common constraints include: budget, schedule, technology and politics. Potentially, if these constraints are not addressed properly, they can lead to overwhelming problems late in the program. Knowing the relevant constraints early in a program facilitates the establishment of realistic program objectives. Additionally, knowledge of the relevant constraints facilitates the assessment of alternative choices when problems arise.

In summary, the definition of risk associated with program management includes the following. First, program risk can be assessed differently based upon the individual risk propensity. Second, a higher possibility of the program deviating from the original objectives equates to a higher degree of risk. Third, a program manager is given resources such as, budget, time, and personnel to overcome the difficulties and to satisfy the customer. These factors clearly indicate a program manager should be intimately familiar with risk management since he or she is responsible for the entire program.

Risk Factors and Risk Drivers in Weapon Systems Acquisition

Risk Factors in Weapon Systems Acquisition. Risk exists in whatever people desire to achieve, and objectives define the existing areas of risk. For example, if one needs to reach Paris by next Monday to address an important seminar, he or she prepares the material and has many alternative routes for getting to Paris. However, he or she might be late to the seminar (objective) due to many possible delays, e.g., transportation problems, loss of ticket, loss of material, unaware of time difference, jet-lag, sickness, etc. This example illustrates that risks will occur when people pursue destination. And further, if the process is not adequately addressed, the original objectives may be jeopardized. In weapon systems acquisition, program managers use resources to design, develop, test, produce, deploy and support a system that is on time, with an acceptable quality, and within budget. In systems acquisition, the objectives are to control schedule, cost, and performance. To assist in determining where the risks will most likely occur, the DoD 4245.7-M "Transition from Development to Production" provides a template for tracking the system design, test, production, facilities, logistics, and management. The template is arranged in a logical sequence from a typical program manager's viewpoint (5:1-8). Hence, program risks can be categorized as Funding, Design, Test, Production, Facilities, Logistics, and Management, with funding influencing every other risk area. Understanding these risk areas is fundamental to risk identification and control.

Risk Drivers in Weapon Systems Acquisition. Program managers and senior acquisition executives who are concerned about the program will always want to know the current status of a program and the cause of any problems. They will want to know about any factors which prevent management from achieving acquisition objectives. In order to address program specific risks, it is important to understand the three distinct stages of science: classification, correlation, and effect-cause-effect (1:23). More specifically, science is a process of observation, know-how, and explanation. The ultimate goal of applying these stages is to predict the outcomes of entirely new situations. Before the unwanted outcomes become irreversible, programs should be evaluated by criteria that are observable and classifiable. For weapon systems acquisition, those criteria are best described in the "Transition from Development to Production" template. These criteria, if studied in advance, will enable program manager to recognize and classify risk factors if and when they occur.

Based on observations, criteria that contribute to the negative consequences in systems acquisition should be identified for risk reduction. What can be correlated to the risk and its drivers in acquisition? Before referring to the available template and the other DoD publication, Best Practices, it is important to note there are two general sources involved: namely, the subjective and objective environments.

Subjective environment. Subjective environment risks might be caused by:

A. Unqualified managers and/or engineers responsible for the program.

B. A lack of enthusiasm for the jobs.

C. Poor organizational structure, communication, and coordination.

D. Ambiguously defined requirements.

E. Inadequate program plans.

F. Impractical propensity for risk taking by the program manager.

Objective environment. The following objective environments might also cause risks:

A. Resource constraints: such as limited manpower, budget, and insufficient time for conducting the necessary tasks.

B. Political interruptions.

C. Changing threat.

Risk Management

Sun Tzu, the martial god in Chinese military history developed a doctrine in his offensive strategy which states "He who has a thorough knowledge of his own conditions as well as the conditions of the enemy is sure to win in all battles" (10:84). For risk management, knowing one's and enemy's conditions refers to risk planning and risk assessment. Figure 1 shows the relationship of different terms in the risk management process.

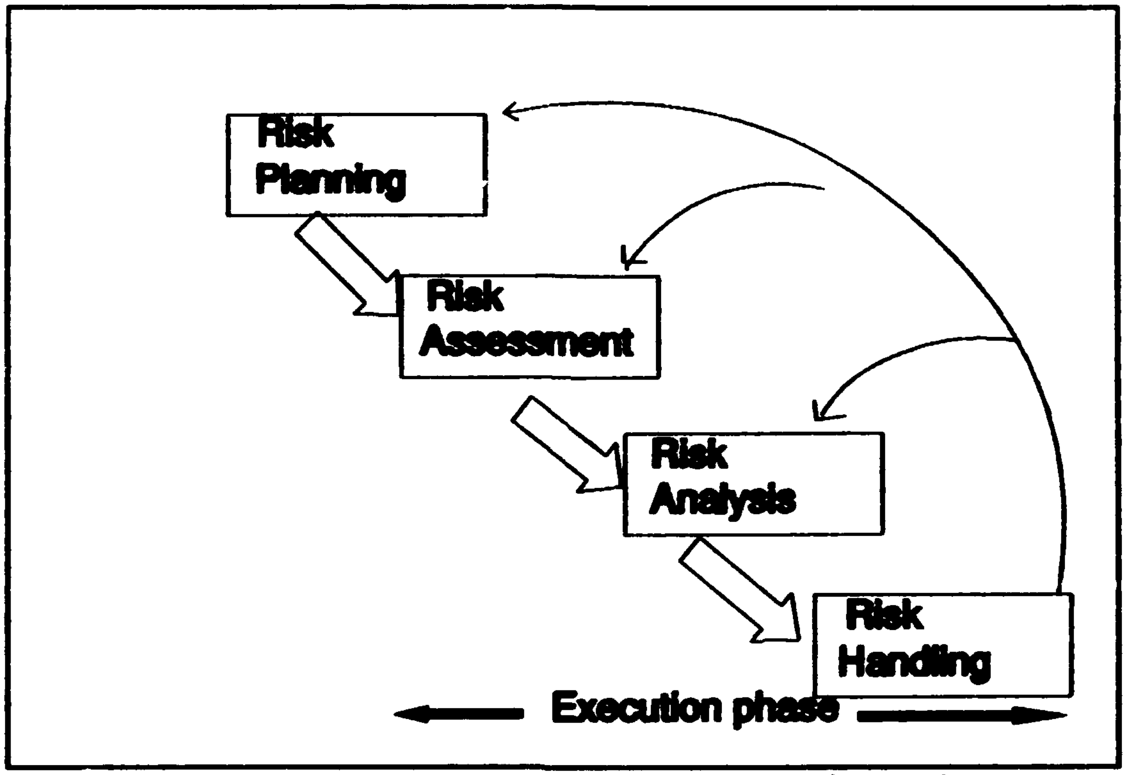


Figure 1. Risk Management Process (6:5-2)

The four parts of the risk management process can be categorized into two phases, planning and execution. Risk planning means to document the risk management plan. In most cases, program managers have almost total freedom to structure this document to suit their situation. For proper risk planning, one needs to master the subjective and objective environments. Understanding these environments will help to generate a proper acquisition strategy which should prevent the program from becoming unmanageable.

Risk execution involves assessment, analysis and handling of risk. Risk assessment consists of both risk identification and risk quantifying. It also appears that risk identification has two phases, i.e., prior to and during implementation of the program. Knowing the environments, a program manager should be able to foresee how his or her program will likely result if strategies are not adequately considered and formulated at the outset of the program.

A surprise finding made in risk assessment in 1989 at the Air Force Institute of Technology (AFIT) was that the processes/techniques suggested by the DSMC were not well known by ASD mid-level program managers (4:80). Nevertheless, the study also concluded that most of those ASD mid-level managers desired to attain formal training to help them measure acceptable levels of risk and to decrease the probability that they will make inaccurate decisions (4:91-97).

According to Risk Management Concepts and Guidance, the execution portion of risk management has seven steps as outlined at the Table 1 (6:5-2+):

Table 1

Risk Management Procedures

Step	How/What to Do
1. Evaluate the achievability of the proposed project against the plan.	
2. Identify the risk areas.	1. Develop a structure to systematically comb through the program and issues (i.e., Work Breakdown Structure, checklist) 2. Conduct expert interviews. 3. Review analogous system data. 4. Evaluate program plan. 5. Examine lessons learned document (Transition Template).
3. Quantify the risk areas.	1. Develop a consistent scheme for rating risk. 2. Assess the likelihood of the risk occurring. 3. Assess the impact severity in terms of cost, schedule, performance, etc.
4. Document the risk areas.	1. Develop and maintain a management watch-list. 2. Develop an effective communication scheme so input from all functional areas is received.
5. Conduct risk analysis.	Examine the results: 1. In terms of performance, time, cost. 2. By system/subsystem. 3. Of funding profiles. 4. Based on criticality. 5. In terms of consistency with analogous systems. 6. Of "what-if" analysis.

Risk Management Procedures (Cont)

6. Determine appropriate handling option.	1. Avoid the risk. 2. Share the risk with another party. 3. Assume the risk. 4. Control the risk.
7. Implement the option.	

Having a clear understanding of risk definition and the environments that potentially cause risk will not necessarily eliminate the risk. Execution of risk assessment and analysis are the two major challenges for achieving successful risk management.

Appropriate techniques suggested by the DSMC publication, Risk Management Concepts and Guidance will first be summarized and then risk identification techniques will be reviewed in more detail.

Summary of Techniques for Defense Acquisition Risk Assessment and Analysis.

A. Techniques for Risk Assessment. The DSMC publication, Risk Management Concepts and Guidance identifies several risk assessment techniques:

1. Analogous Comparisons/Lessons Learned-Examine the "success, failure, problems and solutions of similar existing or past programs (6:5-7)".

2. Expert Interviews-Obtain the judgment from technical experts in the field to a) identify those areas

which may be risky and b) the extent of risk involved (6:5-4).

3. Independent Technical Assessment-Obtain an alternative assessment of the progress and risks of the technical aspects of the program from a group of experts not associated with the developing organization (6:5-55).

4. Plan Evaluation-Compare plans and other documentation to look for contradictions, inconsistencies and missing information (6:5-11).

5. Transition Templates-Conduct a comprehensive and disciplined review of a program with the known high risk problem areas for the project and the best known solutions (6:5-18).

B. Techniques for Risk Analysis. Additionally, the DSMC publication presents several risk analysis techniques:

1. Decision Analysis-Develop a math equation which states the objective function to be maximized or minimized (e.g. profit, cost), the alternative choices available to the decision maker, the mutually exclusive and collectively exhaustive events (states of nature) which may affect the outcomes, and the probabilities for the occurrence of each event (6:5-21).

2. Estimating Relationships-Develop a mathematical equation for the relationship between certain

program characteristics and the cost or schedule to the program (6:5-26).

3. Cost Risk/Work Breakdown Structure (WBS) Simulation Model-A computer simulation model can be used to aggregate total program costs based on different probability distributions of cost uncertainties within lower level WBS elements (6:5-37+).

4. Cost Performance Report (CPR) Analysis-Review contractor CPR to identify cost or schedule variances and evaluate likelihood of causes, potential impacts and sufficiency of remedies (6:5-54).

5. Independent Cost Estimates-Obtain a total cost estimate from individuals, not associated with the developing organization, who use procedures and techniques (6:5-56).

6. Life-Cycle Cost Analysis-Use an existing or modified computerized LCC model, which consists of a series of equations which compute program cost quickly for trade-off analysis, sensitivity analysis, production rate and quantity analysis, etc., based on product and program information (6:5-34).

7. Network Analysis-Develop a flow of activities and events which identifies relationships, timing and priorities (6:5-28).

8. Performance Tracking-Conduct periodic reviews

of technical performance indicators compared to performance goals and look for breaches in pre-established alert zones. This technique advocates the use of a Technical Risk Assessment Report, which is updated monthly based on working level data (6:5-45+).

Risk Identification. People have different perceptions of risk. They often not only differ in quantifying the risks but also in the method used to identify the risk. Several techniques for risk identification have been suggested by the DSMC; they are: expert interviews, analogy comparison, evaluation of the program plan, and the transition template (6:5-1+). Each technique will be discussed in detail.

A. Expert Interviews.

1. Description of the Technique.

> One of the most critical elements or tasks in risk assessment is that of obtaining accurate judgement from technical experts. Unfortunately, this is an area where it is easy to make errors and therefore obtain information that is inaccurate. The interviewing of technical experts to gain information regarding risk is critical for two reasons. First, the information identifies those areas which are perceived as being risky (risk identification). Second, it provides the basis for taking the qualitative information and transforming it into quantitative risk estimates (risk quantification). (6:5-4)

One might then ask who qualifies as an expert? It is frequently difficult to identify experts. There is no measurement to accurately determine whether a person is a real expert. Expertise dependent upon his or her experiences and achievements. Though it is important to state that one with less experience is not necessarily less capable than one with more experience. Moreover, an elder manager who has served a longer time in program management isn't always the most competent. So, a safe way of interviewing experts might be to carefully stratify the population and then take samples in accordance with investigative interest or interview all experienced people if time permits.

2. Applicability. The DSMC guidance suggests that Expert Interviews are useful and recommended for all programs. Following this technique, it is logical to pursue potential actions and alternatives as well as information pertaining to potential impacts. With this technique, it is also possible to achieve higher cohesion in the organization if brainstorming or the Delphi Process can be incorporated.

B. Analogy Comparison.

1. Description of the Technique. This technique is often called "lessons learned" and is self-explanatory. With this technique program managers compare the characteristic of the new program with past or existing programs, and learn lessons from others' mistakes. This is a feasible approach, but, similarity between programs is

essential to perform the comparison, otherwise misjudgment and erroneous conclusions may result (6:5-7). In other words, the validity of the data collected drives the appropriateness of the technique. The analogy may rely on similarities in technology, function, acquisition strategy, manufacturing process, etc. The key of the technique emphasized by the DSMC guidance is to understand the relationship between the program characteristics and the particular aspect of the program being examined. The technique may be time-consuming. In addition, an older system may be somewhat similar, but large technology changes might result in lessons that are no longer valid.

2. Applicability. This technique is useful for all phases and aspects of a program. The DSMC guidance suggests that the technique is particularly valuable when a new system is primarily a new combination of existing subsystems, equipment, or components for which recent and complete historical data is available.

C. Evaluation of Program Plan.

1. Description of the Technique. Plan before doing. Following the plan cannot guarantee success; however, it can mitigate the risk if any deviations are known from the start. The Evaluation of Program Plan technique uses the Work Breakdown Structure (WBS) to examine whether the specification requirements have been addressed,

the schedules are feasible, and the cost is reasonable. These concerns should be incorporated into the contracts of the program. It is obvious that a prerequisite is required; that is, the planning must be as complete as possible in order to be evaluated properly. Using this technique reflects most of the realities of risk identification related to the specific program. The relationship among WBS, SOW, and Specifications is shown in figure 2.

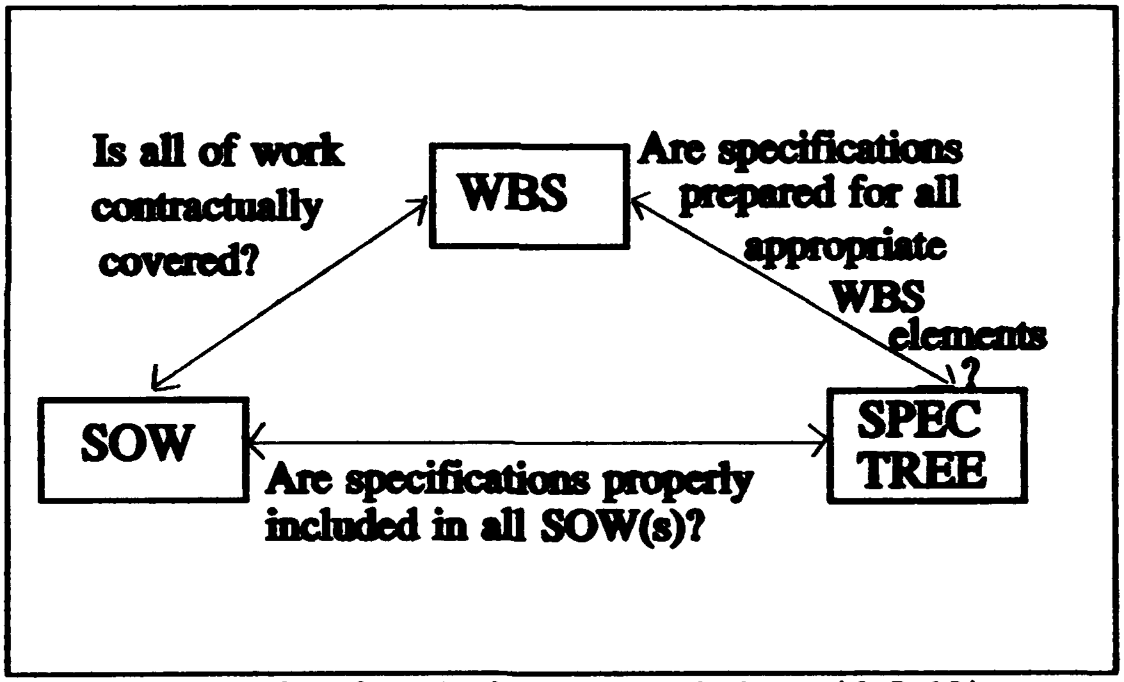


Figure 2. Plan Evaluation Technique (6:5-12)

2. Applicability. The DSMC guidance emphasizes that this technique is useful where technical, programmatic, and supportability risk identification is desired. The usefulness for cost and schedule risk

identification is considerably less; however, any missing information concerning deliverables which would impact cost and schedule could be indicated. The technique would be most applicable to the engineering-and-manufacturing development and production phases.

D. Transition Template.

1. Description of the Technique.

This template, Transition from Development to Production, was built in 1985 based upon actual experiences in DoD's past acquisitions, and is considered the most current practical template because its validity is drawn from experiences. The major step calls for individuals or groups to evaluate themselves in relationship to the solutions and risks suggested in the template. This template also describes methods for avoiding or reducing the risk.

In addition to the template, the US Navy published a manual in 1986 which is also suitable for risk identification called "Best Practices, How to Avoid Surprises in the World's Most Complicated Technical Process." The manual provides detailed illustrations concerning program traps and their consequences, and also provides a checklist for the risk management. The publication was derived from DoD Directive 4245.7-M, the Template.

2. Applicability. Because of the acquisition areas covered by the template and the fact that the lessons learned are from actual experiences, the DSMC guidance highly recommends the use of this technique for most programs, either independently or in conjunction with another technique. The template can be used for any size program at any phase of development (6:5-19).

Application of the technique is dependent on the situation the program is involved in as well as the program manager's experience. This technique is particularly useful if the program is a first-of-its-kind, or the risk analyst has few experienced experts to consult and few similar programs to compare. In these cases, he or she probably has no choice but to use either the transition-template technique or evaluate-the-program-plan technique, both of which are powerful indeed.

The Psychology of Risk

"The degree of risk existing in a given situation is a reflection of the personality of the risk taker" (6:4-8). People perceive risks differently, depending upon the nature of the risk and their individual experiences. Risk perceptions are influenced strongly by issues of choice and control, which means that risks often seem riskier to people if they have no control over the source and management of the risks. Perceptions of risks are also influenced by the benefits derived from accepting the risk (28:9). Therefore, the variance in magnitude of risk perceived by experts for a given matter could be very large due to different personalities. This subjective involvement of personality differences in risk appraisal is why "Expert Interviews" often conflict and produce inaccurate information. The psychological dimension of overestimating or underestimating true risk was confirmed by a study where people estimated frequency of lethal events and is summarized in Figure 3.

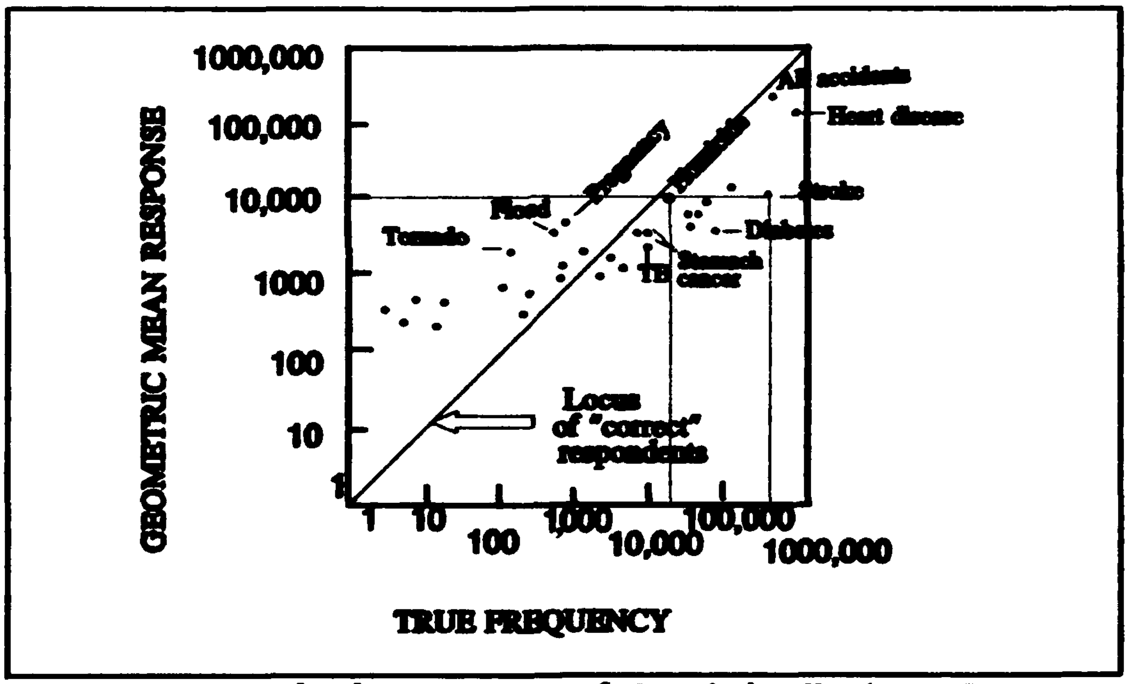


Figure 3. Judged Frequency of Death by Various Causes (30:128)

In Figure 3, note that on the left, the points are systematically positioned above the "correct" line and on the right, systematically below it. Notice that homicides were incorrectly thought to be more frequent than diabetes and stomach cancer. Homicides were also judged to be about as frequent as stroke, although the latter actually claims about 11 times as many lives. Also, the incidence of death from tornadoes and pregnancy was greatly over-estimated (30:129). These results illustrate the potential shortcomings of expert interviews. One study of risk behavior in managerial decisions revealed that, based on the REACT model, (i.e., Recognizing, Evaluating, Adjusting, Choosing, and Tracking), **risk takers tend to underrate risks, while risk averters tend to overrate risks** (31:34).

Another interesting finding in the psychology of risk arises from an investigation conducted in 1960's. Stoner used a personality assessment instrument, the Choice Dilemmas Questionnaire, to test the hypothesis that groups stifle risk-taking. Stoner concluded that the recommendations offered by individuals who are in a group situation were riskier than when acting alone (30:124). The fact is that people's anxieties seem to be reduced in group situations because others are in the same boat, or group situations tend to cover incompetency of individuals when involved in decision-making.

Risk Quantifying

For the purpose of controlling or diminishing the risk,

risk management should be based on something measurable in which an "alternatives comparison" can be conducted. Hence, to quantify the magnitude of the risk is highly recommended. Figure 4 illustrates the basic concept of quantifying risk magnitude.

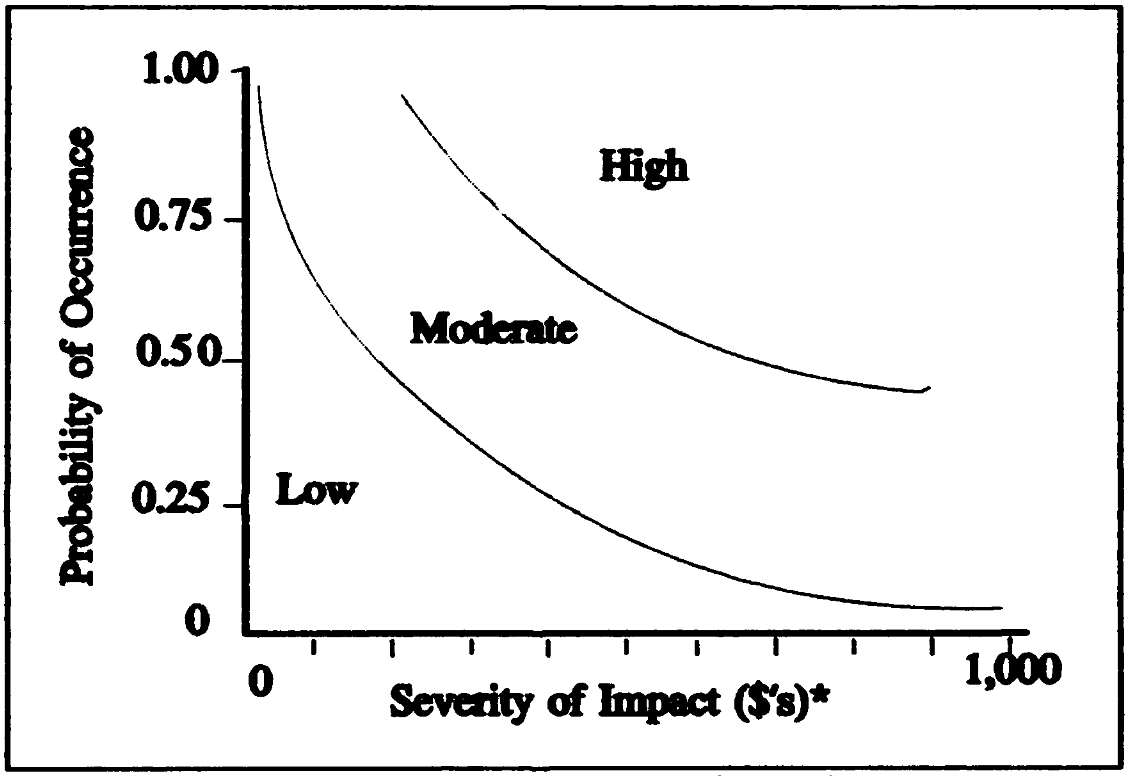


Figure 4. Risk Rating (6:4-9)

First, make a judgement, based on experience, on the likelihood of occurrence of the unwanted outcome in terms of probability. Second, measure the severity of impact based on cost, schedule, performance, or other measurable factors or combinations.

Next, consider the dotted lines in the figure which represent the watershed of risk magnitude. The positioning of the boundaries between the different magnitudes of risk depend on the program manager's propensity for risk taking as well as personal experience. One could draw the dotted line that distinguishes low risk from medium risk in a much more convex-to-the-origin manner if he or she is somewhat more conservative than others. On the other hand, he or she might be more of a risk-taker. In that case, the dotted line would be less convex-to-the-origin.

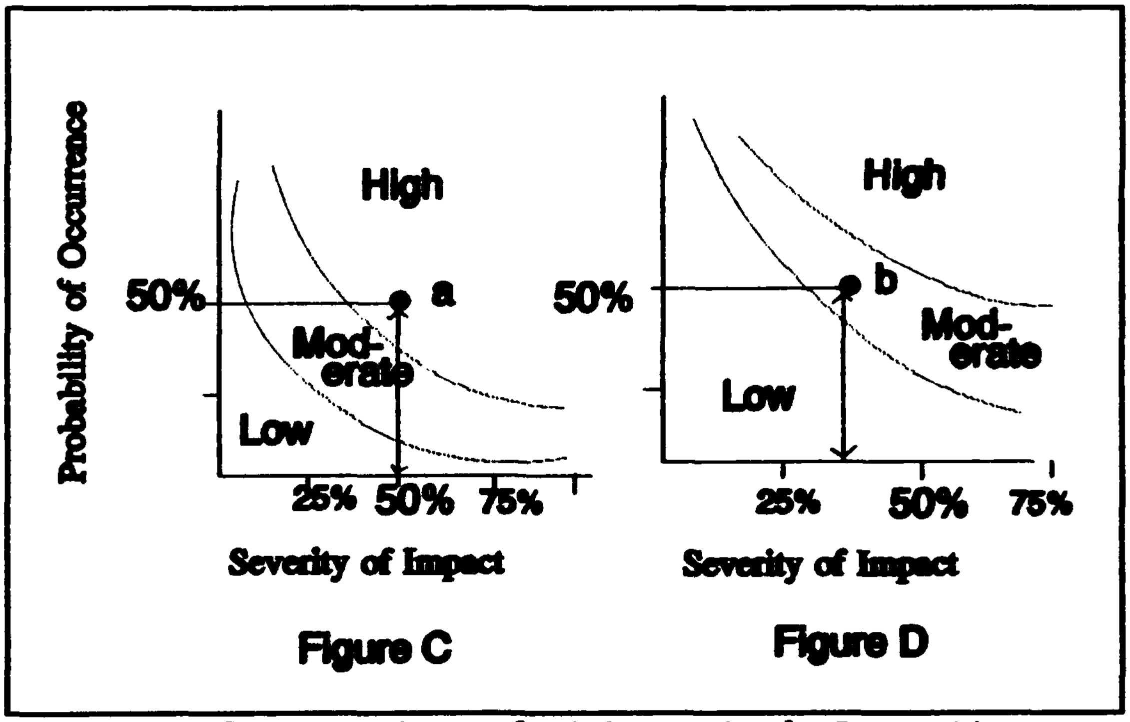


Figure 5. Comparison of Risk-Magnitude Perception

Figure 5 illustrates how the magnitude of risk perceived differs individually. Figures C and D could be different perceptions of risk for different aspects of the program by the same person. It could also be referred to as the distance from consensus with regard to magnitude and impact of risk on the same aspect of the program as viewed by two people. For measuring magnitude of risk with respect to the severity of impact on different aspects of the program, e.g., cost and performance, one might view the impact of the occurrence to cost as more severe than the impact of the occurrence to performance. Therefore, the severity of impact is different and, of course, the magnitude of risk is different.

Which dotted line is drawn correctly in terms of risk management? To a large extent, the answer depends on the particular program. DoD Directive 5000.1 states "Acquisition strategies and program plans shall be tailored to accomplish established program objectives and to control risk . . . " (19:1-4). All efforts including risk management, are oriented toward the program objectives which are different for each case. For example, if the objectives of the system development are to deploy the system as early as possible and to exploit specific technologies, a safe way to draw the dotted lines might be shallower (less convex-to-the-origin) in cost risk but steeper (more convex- to-the-origin) in schedule risk. Because shallower dotted lines yield a larger area between them than steeper lines, the severity of impact to the program should be lessened.

Acceptable Risk

DoDD 5000.2 states that all actions shall be taken to identify, assess, and eliminate or reduce risk to an acceptable level in selected areas (e.g., cost, schedule, technical, producibility, etc.); and the total program (2:15-15). When making decisions at an individual level, the choice of whether to accept a risk is primarily a personal decision, e.g., choosing whether to eat foods known to have trace amounts of toxic substances. On a societal level, the decision to accept or not accept a risk is more difficult (28:17). One actually does not choose an acceptable risk, rather he or she selects an alternative with a certain degree of risk that is expected to result in the lowest negativity (12:4). After identifying the risks, the next task would be to decide whether the risk is acceptable and why. No level of risk will receive universal acceptance, but eliminating all risk is impossible. Thus, decision-makers typically identify levels of risk that are tolerable or acceptable in light of other factors such as the costs of risk reduction, or availability of substitutes for that activity or substance which poses the risk. Unfortunately, this is not an easy question to answer because the magnitude of risk is perceived differently in everyone's eyes, depending on the propensity for risk taking. To understand the nature of difference and to illustrate the "best" way of deciding acceptable risk, the Cost-Risk Figure below should be helpful.

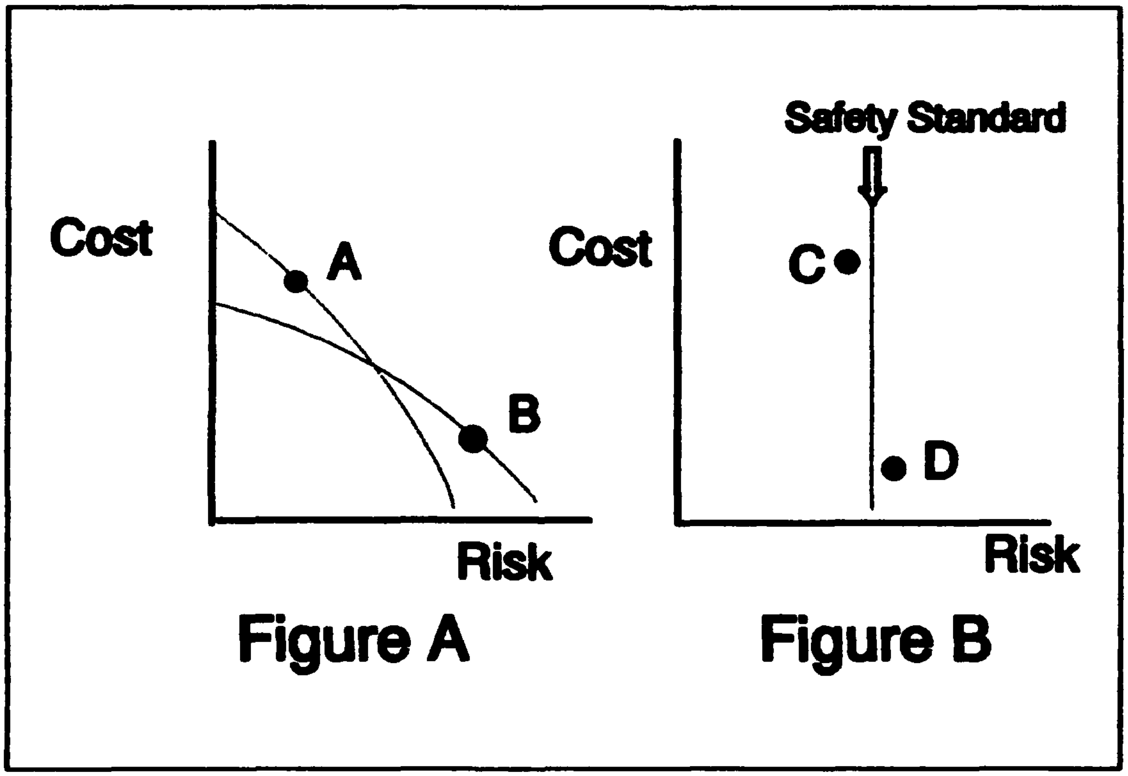


Figure 6. Cost-Risk Figure (12:5)

Figure 6 shows that some risks are actually cost-compensable. The two broken-line indifference curves in figure A represent the options of taking higher risk in return for great reduction in cost at point B or, to pay higher cost for minimizing the risk at point A. One might choose to avoid high risk or to reduce cost depending on his or her view of the matter. However, choosing the proper option is a dilemma, Hence, these decisions require sufficient data to assess the situation in order to make the best choice.

In figure B, a safety standard is provided to define the region of acceptable risk. A standard may facilitate a decision, but it isn't necessarily a panacea, because every option is accompanied by some negative aspects, such as cost. Also, there are still some people who would like to choose point D instead of point C to save money since the distance from D to C might be considered small and in spite of the fact that D is already over the safety limit. Nevertheless, a defined standard or baseline provides a fairly clear boundary to support decision-making.

In defense system acquisition processes, the baseline summarizes key performance, support, cost, and schedule thresholds for each milestone to support a program manager's management strategy and risk-taking. In 1986, The DoD started baselining program objectives which were specified in DoD Directive 5000.45 (now incorporated into 5000.2, Part 11). Even though acquisition stability may not yet exist due to changing requirements and other reasons, the baseline provides a guide to program management for trading-off cost, schedule, and performance, until the complexity of the program is determined.

Another challenge which confronts program managers is the selection of suitable criteria for baselining cost, schedule and performance. Baselines are adjustable from phase to phase dependent on the changing acquisition strategy. For example, before the Engineering & Manufacturing Development phase, program management can use a prototyping approach to assess cost and performance trade-offs, to define program objectives for the development baseline, and to determine contract specifications for phase II (2:5-D-2). In later phases, production units may be available to support baseline requirements.

Summary

Risk is not a welcomed phenomenon, but one must comprehend the characteristics of risk before trying to minimize its effect. Understanding the environment of the defense program can help the program manager make an educated choice for risk assessment and control in the weapon systems acquisition process. However, implementing risk assessment and risk handling properly requires either experience or education. The techniques reviewed in this chapter provide a brief but useful reference for risk identification and assessment.

In this chapter, risk identification, risk quantification, and methods to determining acceptable levels of risk have been briefly reviewed. The next chapter will discuss the methodology used to conduct this research effort.

III. Methodology

Overview

This chapter describes the research methodology used to identify the major risk factors in major weapon systems acquisition in the ROCAF. It presents the methodologies employed to determine the degree of risk associated with these major risk factors as well as primary causes. Next the discussion explains the research population, research sample, and data collection procedures. Lastly, the chapter describes the method used to analyze the data collected in this study.

Method Selection

In chapter II, several techniques were introduced for risk identification, for example, Expert Interviews, Program Comparison, and so forth. Although each technique can effectively identify program risks, Expert Interviews is considered the most appropriate for ROCAF acquisition risk identification for two reasons. First, expert interviews provides aggregate responses which represent a majority of opinions, and that will help to minimize the conflicts between organizations, and between individuals. Second, the findings and recommendations will translate directly to the ROC Army and Navy which have the same acquisition environments as the ROCAF. In addition, there are several considerations which preclude the adoption of the other techniques:

A. Since major defense acquisition started just twelve years ago in the ROC, there are still very few completed programs from which to draw data and lessons learned. In comparison, the United States Air Force (USAF) Aeronautical Systems Center (ASC) has completed many programs from which comparisons can be made.

B. Although the nature of systems engineering conducted in the acquisition process might be the same, it would be simplistic to think that what works in the USAF will necessarily work in the ROCAF. An analogy to this can be found in the automobile industry where it would be simplistic to think the same managerial style used in Japan will necessarily work in the U.S. (16:216). Hence, one can not employ risk identification techniques based solely on program comparisons with the ASC. Additionally it is quite possible that the difference in cultures might result in different management styles.

C. The environment or the constraints might be different. These differences will introduce different acquisition strategies that are established to achieve specific program objectives. Those strategies, conceivably, will influence the perceived risk magnitude and the selection of associated risk abatement.

D. Evaluation of the Program Plan is a technique used for a specific program. The intent of this research is not to study a specific program's risk, but rather to offer a generic perception of risks that currently exist in ROCAF weapons acquisition.

Research Population

"Experts" in the ROCAF acquisition process are defined as mid-to-top level managers who are involved in day-to-day administrative and technical management and decision-making. These managers would be equivalent to personnel with U.S. Air Force specialty codes (AFSC) 27XX and 0029. Overall, the population of "experts" can be referred to as those mid-to-top level managers distributed in defense programs within the MND, services and CSIST who are concerned with the day-to-day management aspects of both major and non-major programs. Currently, the population size consists of no more than two hundred managers.

Sampling and Sizing

A good sample has both accuracy and precision (13:278). In order to avoid bias and sampling errors, the ideal survey would include the entire population. However, the sample of interest will be drawn mostly from the ROCAF because of the difficulty of assessing both the Chinese Navy and Army and because of the time limitation. More specifically, the mid-to-top level acquisition managers in the ROCAF and CSIST as well as MND will be surveyed. The number of managers in current ROCAF acquisition programs make up approximately more than one-half of the total population due to the large scale of the IDF and other ROCAF programs. Since the number of those managers includes a large share of the current population, about 100 out of 200, it is not necessary to calculate a required sample size specifically. That is to say, basically the sample size will include these 100 managers.

Furthermore, although day-to-day experiences may nurture a manager's competence, there are two reasons why stratified sampling will not be used to differentiate or to weight the sample. First, it is difficult to determine whether experience alone will directly determine a manager's level of competence or expertise. Second, the survey, in order to secure content validity which will be discussed shortly, allowed the respondents to remain anonymous. Therefore, the researcher cannot give weight to those experienced managers who do not identify themselves.

Those managers with very little experience (less than six months), were excluded from the sample. These new managers were excluded because of the time required for orientation to the acquisition management and the low utility of the information which could be obtained from those individuals. Incidentally, lack of experience might have made those individuals more reluctant to complete the survey. And inclusion of reluctant respondents may produce more error as a result of the poor quality of their reporting (24:60).

Data Collection

The procedures and considerations concerning the data collection are categorized into four segments as follows:

Scale. Magnitude of risk measurement is subjective. An ordinal scale which allows the respondents to rank their own preferences will be used for this study. A 5-point scale measurement-Very high, High, Moderate, Low, Very low-will be used rather than a 7-point scale due to the difficulty in differentiating the magnitude of extremely high from very high and extremely low from very low in risk assessment. Besides, it is meaningless to distinguish extremely high risk from very high if indeed both assessments warrant comparable levels of management attention and intervention.

For risk assessment, DoDD 5000.2 states that risk ratings of high, moderate, or low for each major subsystem and the overall system will be used (2:5-B-2); which equate to a 3-point scale rating. Nonetheless, if "high risk" was selected in most subsystems in a program, the management would need further distinctions. These additional distinctions would be helpful since available resources are limited and these distinctions would help to prioritize the application of the resources for risk management.

<u>Surveying Method</u>. A questionnaire was developed and mailed to the experts. The reasons for this strategy are as follows:

A. A mail-survey is faster and more economical.

B. A mail-survey provides respondents with more time to consider the problems in-depth before answering the questions, whereas face-to-face personal interviews have the disadvantage of little time for consideration.

C. A mail-survey allows respondents to mention the real risk drivers because they have the choice of remaining anonymous whereas personal interviews might make respondents hesitant to answer the questions truthfully.

The questionnaire includes four segments of investigative questions. The first segment asked respondents to evaluate themselves in terms of competency in program management and propensity for risk-taking as well as other personal data which will be used to support and explain the findings. In the second segment, respondents rated the specific risk factors in the following areas: performance, supportability, cost, schedule and management. In the third segment, respondents ranked alternative risk drivers which were based on the "Transition from Development to Production" template and the Navy Best Practices publication for any risk factors which were rated as very high, high, or moderate. The last segment solicited any additional comments on acquisition which could contribute to this research. The English version of the questionnaire is attached in Appendix A.

Validity Control. In order to secure the content validity of this research, careful attention was placed on the design of the questionnaires. This is especially important when applying the Expert Interviews technique (6:5-5). The content validity of a measurement instrument is the extent to which it provides adequate coverage of the topic under study (13:180). DoDD 5000.2 recommends using the template in DoD 4245.7-M "Transition From Development to Production" (2:5-B-3).

Use of the template, which serves as a tool to visualize the pitfalls of the DoD programs, alleviates the burden of risk management (6:1-4). In addition, each critical problem identified in the template corresponds to a checklist and trap list in the Best Practices which can be referred to when building the questionnaires (11:2-0). Most importantly, the template and checklists published by DoD were based on real experience and include the most practical and specific aspects which could result in risk. In addition, collecting information about self-evaluation of risk propensities of the respondents helped to modify the measured risk-magnitudes which might have been over- or under-estimated due to the differences of personalities of the respondents.

Pilot Run. Translation of the questionnaires from English to Chinese was required. The researcher performed the translation and asked Chinese students currently studying at the Air Force Institute of Technology to verify the appropriateness of the translation. This provided additional validity to the research. A translated Chinese questionnaire is attached in Appendix B.

Data Analysis

Reviewing the objectives of this research stated in chapter I, the purpose of the study was to try and expose the risk factors as well as identify the risk drivers from selected candidates. The appropriate methodology for data analysis should be discussed in terms of research objectives.

In chapter I, the purpose of this research was introduced as the following:

A. To explore the magnitude of potential major risks in terms of performance, life-cycle cost, schedule, management and supportability in the ROCAF's major systems acquisition process.

B. To know and understand risk drivers that cause the associated risk in weapon systems acquisition in the ROCAF.

For the first objective, descriptive statistics will be used to measure the magnitude of the risks. These results will reveal the magnitude of risk in performance, supportability, schedule, life-cycle cost and management in weapons acquisition because of the large sample size (24:7). More specifically, a pictorial representation showing relative frequency distributions of magnitude can be constructed using a histogram. The questionnaire results provide the frequency for a specific risk factor. A qualitative measurement can be made with a horizontal line of equal interval. Then, one needs only to construct rectangles with heights proportional to the frequencies (25:9+). Thereby, a clear, easily understandable relative distribution of the risk magnitude of performance, supportability, and so forth can be presented. However, it's believed that before drawing conclusions about the risk magnitudes of the risk factors based on descriptive statistics, a careful study of the risk propensities of the respondents will be necessary. This allows one to draw a conclusion because the true risk measured of a risk taker will be somewhat different than that measured by a risk avoider even if the magnitudes of risk are equally rated.

For the second research objective, identifying the causes of the risks, nonparametric statistics will be used to determine which factors cause the most risk. There are two reasons for adopting this method:

First, nonparametric procedures forgo the traditional assumption that the underlying populations are normal (21:1). The characteristics of the ordinal scale used to rank the causes of specific risk and the distribution of those selected causes of risk can not always be considered a normal distribution. Moreover, the selected causes of specific risk might be somewhat related to each other, for example, if the primary reason of resulting performance risk was a poorly-defined requirements; the unclear requirements might have resulted because of limited time or because unqualified personnel were responsible for translating the mission needs. On the other hand, the secondary risk driver causing performance risk could be an overall tight schedule for conducting the task necessary. Therefore, those primary and secondary risk drivers chosen are somewhat related to each other, and hence, they were not always independent.

Second, nonparametric procedures are applicable in where the actual magnitudes of the observations are not required, but rather, their ranks (21:1).

These reasons strongly support the selection of nonparametric tests for this research objective. Specifically, the Friedman Test is the most desirable approach to test the equality among the "treatments". The assumptions and procedures for conducting the Friedman test are as follows:

<u>Friedman Test</u>. In a two-way array, the ranks can be shown in the diagram below:

	Treatments				
	1	2	3	...	k
Block					
1	R_{11}	R_{12}	R_{13}	...	R_{1k}
2	R_{21}	R_{22}	R_{23}	...	R_{2k}
3	R_{31}	R_{32}	R_{33}	...	R_{3k}
...	...	...	...	...	...
n	R_{n1}	R_{n2}	R_{n3}	...	R_{nk}
	$R_{.1}$	$R_{.2}$	$R_{.3}$	...	$R_{.k}$

Risk drivers can be considered as treatments, and respondents as block. R_{ij} is the rank of the treatments in the ith block.

<u>A. Assumptions</u>.

1. The n k-variate random variables are mutually independent. (The results within one block do not influence the results within the other blocks.)
2. Within each block the observations may be ranked according to criterion of interest (26:299).

<u>B. Procedures</u>.

1. Hypotheses.

H_o: Each ranking of the random variables within a block is equally likely (i.e., the treatments have identical effects).

H_a: At least one of the treatments tends to yield larger observed values than at least one other treatment (26:300).

2. Test Statistics:

$$K^* = \left[\frac{12}{nk(k+1)} \sum_{j=1}^{k} R_{.j}^2\right] - 3n(k+1) \qquad (1)(27:197)$$

Where $R_{.j}$ is the sum of ranks corresponding to the jth treatment. It can be expressed as the equation shown below:

$$R_{.j} = \sum_{i=1}^{n} R_{ij} \qquad (2)(27:196)$$

3. Decision rule. Reject the null hypothesis at approximate level α if K^* is greater than or equal to $\chi^2_\alpha(k-1)$, where $\chi^2_\alpha(k-1)$ is the upper α percentile for a chi-square distribution with k-1 degrees of freedom (27:197). Actually the chi-square distribution only approximates the distribution of K^*, but the approximation improves as n, the number of blocks, gets larger (28:266).

4. Conduct multiple comparison. When the Friedman test rejects the null hypothesis, pairwise multiple comparisons can be constructed to test and determine if any two interested treatments are significantly different at overall level α, if

$$|R_{.j}-R_{.i}| \geq Z_{\alpha'/2}\sqrt{nk(k+1)/6} \qquad (3)(27:197)$$

Where $\alpha'=2\alpha/k(k-1)$ and $\alpha'/2=1-\Phi(Z_{\alpha'/2})$ (27:197). More specifically, $1-Z_{\alpha'/2}$ is the Z value at α where $\alpha=1-\alpha'/2$. Overall α is a family confidence level that covers all treatments, whereas α' is the significance level for any two treatments comparison. For example, if respondents ranked 4-treatment questionnaire, and if an overall α of 0.06 is used, the treatment comparison will then have a $\alpha'=0.01$, or, 99% confidence interval because for 4 treatments there are 6 combinations (4*(4-1)/2=6), hence $\alpha'=(2*0.06)/[4*(4-1)]=0.01$.

In addition to rating risk magnitude and ranking risk drivers, comments on risk and why the risk drivers existed were also solicited; from which, both findings and recommendations were made.

Research Limitation

As stated previously, risk assessment is dependent upon one's insight. It is also difficult to judge whether the manager is a true expert even though he or she has many years of defense program management experience. Moreover, even if the manager is an expert, experts are fallible (14:33). These are, in fact, inevitable dilemmas when conducting Expert Surveys. The drawn sample might contain some non-experts even though those with has less than six months of management experience were omitted. This dilemma occurs frequently in the current ROCAF acquisition environment because middle-to-high level manager are often too short of their tour lengths to see the program through to completion.

Summary

Chapter III has discussed the population, sample, and methodologies used for risk identification and to collect and analyze data; as well as the limitation of the research. The next chapter will show the results of the investigative questions.

IV. Data Analysis and Findings

Introduction

This chapter presents the results obtained by applying the methodology described in chapter III regarding the risk magnitudes of performance, supportability, cost, schedule, and management; as well as the risk drivers associated with those risk factors. Overall pictorial presentations for risk propensities, self-evaluation of management competency of the respondents, and the risk magnitude of specific risk factors will be shown. These will be followed by the result of the Friedman test which was employed to investigate particular risk drivers. Lastly, comments on systems acquisition management obtained from the additional comments portion of the questionnaires will be summarized.

Review of Investigative Questions

As stated in Chapter I, the following questions will be examined and answered in order to achieve the research objectives, namely the characterization of the risks resident in ROCAF systems acquisition.

Question 1. What is the magnitude of performance risk in systems acquisition? What causes the risk?

Question 2. What is the magnitude of supportability risk in systems acquisition? What causes the risk?

Question 3. What is the magnitude of life-cycle cost risk in systems acquisition? What causes the risk?

Question 4. What is the magnitude of schedule risk in systems acquisition? What causes the risk?

Question 5. What is the magnitude of management risk in systems acquisition? What causes the risk?

Sample Description

The current research population in the ROC defense acquisition process is relatively small compared with the U.S. DoD., and approximately two-thirds of the population are responsible for ROCAF major programs. The researcher only sent questionnaires to those mid-to-top level managers who were involved in the IDF program due to the difficulty in accessing the other services and because of time limitations. In addition, to preclude unqualified responses, the names of extremely young managers with less than six months experience were removed from the questionnaire mailing list. Consequently 72 experts were surveyed, and 54 of them responded to the questionnaires in a timely manner.

Data Analysis

Classification of the Respondents. Before proceeding to analyze the data, the reader should understand that this research did not associate responses with the respondents' organization. Although it is hoped that through this research a mutual understanding of program risk and risk management for both the ROCAF and CSIST can be achieved, it was felt that differentiating respondents by organization would likely increase the friction between the ROCAF and CSIST. This research attempts to understand the respondents in terms of their risk propensities and other self-evaluation information, which were used to analyze the risk factors and risk drivers perceived by the respondents in their questionnaires. For example, if a majority of the respondents were risk avoiders, and the risk magnitude on a specific factor they measured was perceived as high risk, then the "true risk" (population mean) might be somewhat lower than the perception, since this kind of respondent tends to overestimate risk magnitude. The figures in this chapter will show, respectively, the ratio of questionnaire mailings versus responses, risk propensity, and management competency of the respondents.

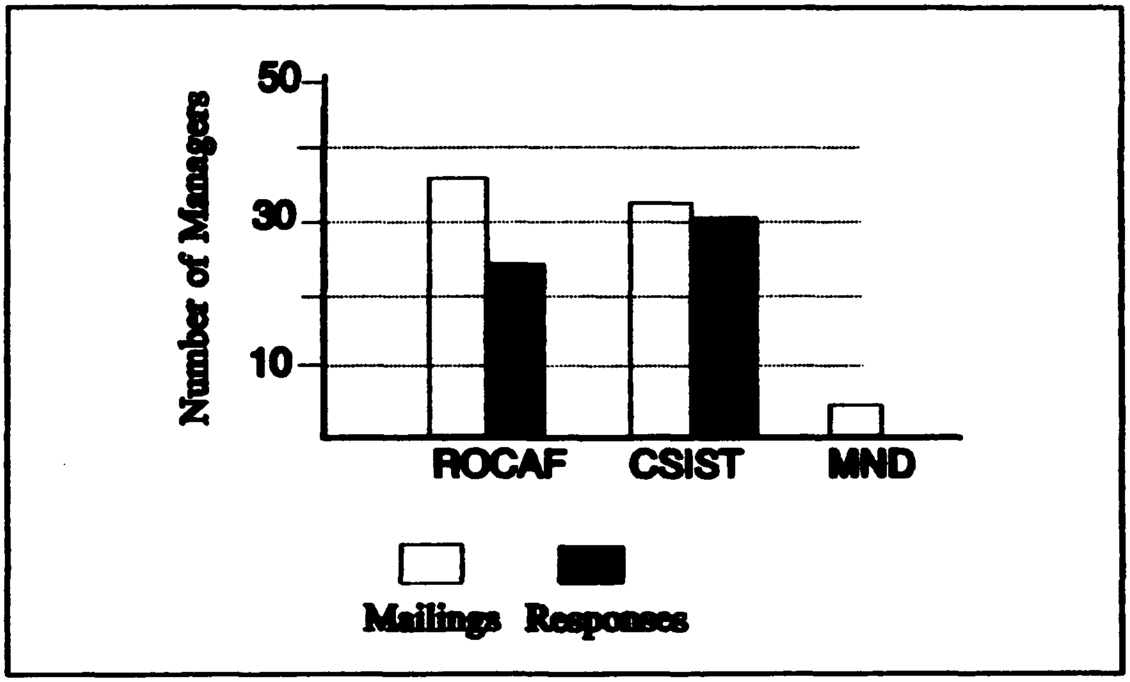


Figure 7. Acquisition Risk Survey Participation

Figure 7 shows that 36, 31, and 5 questionnaires were mailed to the ROCAF, the CSIST and MND, respectively. Although it isn't significantly different, the CSIST had a slightly higher response rate than the ROCAF and MND. The overall response rate was 75% with 64.8% for the ROCAF, 93.7% for the CSIST, and 0% for the MND.

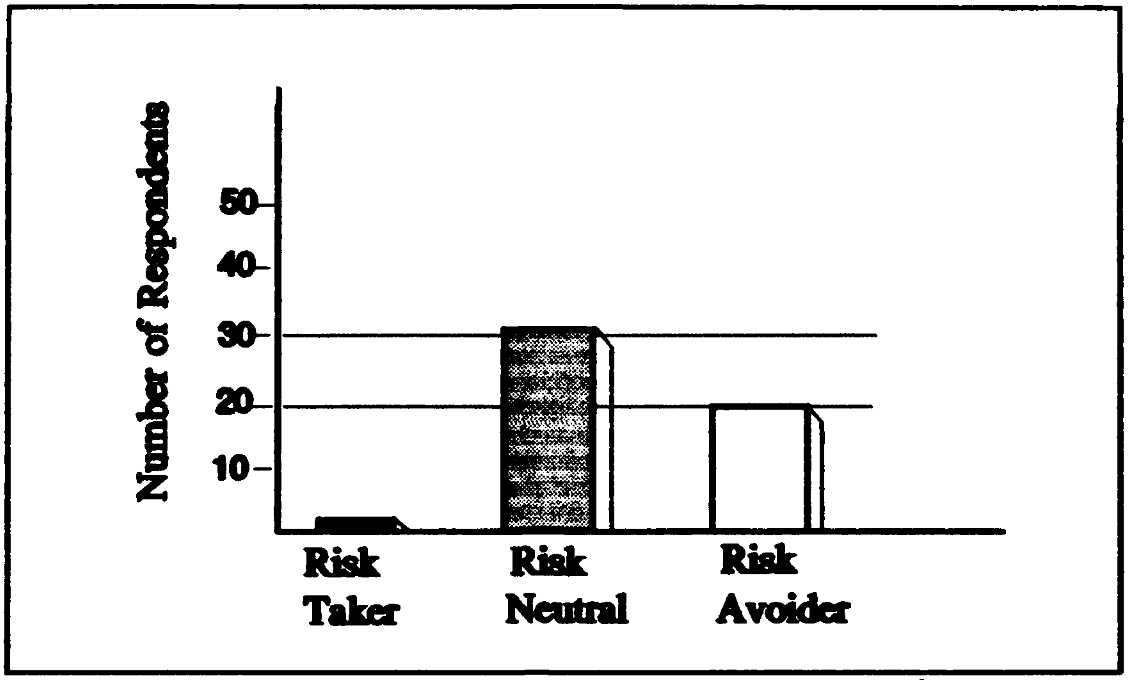


Figure 8. Risk Propensities of The Respondents

Figure 8 shows the risk propensities of the respondents. Notice that the majority (59%) of respondents are risk-neutral, 37% are risk avoiders, and only 4% of the respondents are risk takers. The risk-propensity distribution implies that the risk magnitudes they reported require no modifications. It is probable that the true magnitude of the risk may be overstated by the 37% of respondents who are characterized as risk avoiders.

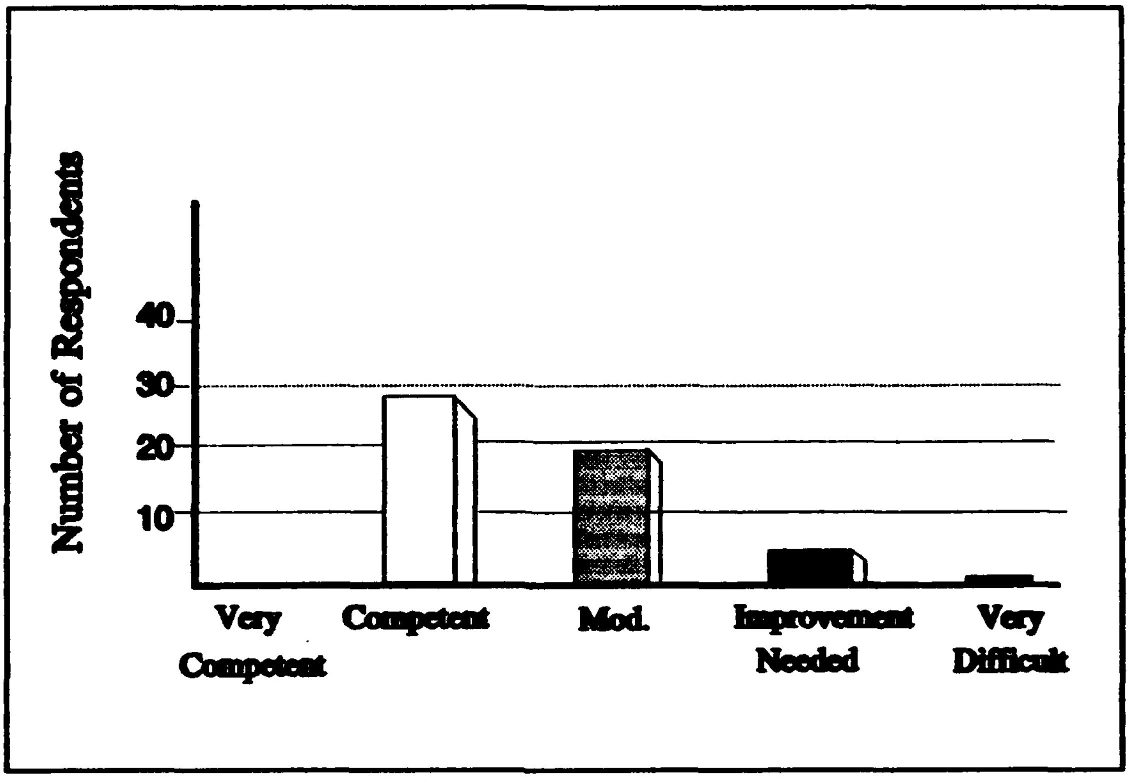


Figure 9. Management Competency

Figure 9 shows the self-evaluated management competency of the respondents. Only one respondent feels the day-to-day management is very difficult, and any types of training won't help to alleviate the frustration. A majority of the respondents, 48 out of 54, or 89% feel they are competent or moderately competent in their jobs. Competent means that although there are some problems, overall day-to-day management and decision-making are basically sound. Moderately Competent means that although occasional problems result in some discouragement, the day-to-day management and decision-making are not too difficult. This explains why many of the managers don't feel further training is needed, despite the fact that none of them evaluated him or herself as "Very Competent" in program management. The findings will be further discussed at the end of this chapter.

Investigative Questions and Findings

Each investigative question is composed of two related questions in which the first question investigates the magnitude of the risk factors: performance, supportability, life-cycle cost, schedule, and management; and the second question reveals the risk drivers which result in a moderate or higher severity of the risk factor.

Performance Risk. **Investigative Question 1. What is the magnitude of performance risk in systems acquisition? What causes the risk?**

A. What is the magnitude of performance risk in systems acquisition? To answer the question, the respondents rated performance risk on a five-point scale of measurement. The summarized raw data can be seen in appendix C. The histogram below shows the risk-magnitude distribution for the respondents.

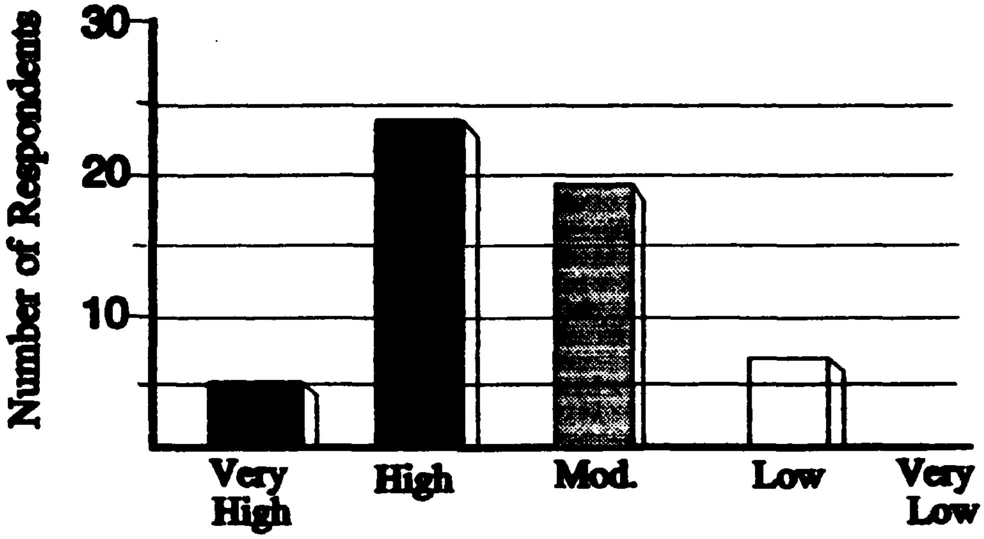


Figure 10. Performance Risk

There were 5 out of the 54 respondents (9.3%) who rated the performance risk in the current acquisition environment as Very High, 23 respondents (42.6%) rated risk as High, 19 respondents (35.2%) rated risk as Moderate, 7 respondents (12.9%) rated risk as Low, and no respondents reported that the risk associated with performance was Very Low.

B. **What causes the performance risk?** First, the Friedman test is used to test whether the performance risk-driver candidates are all equally weighted. If the null hypothesis fails to be accepted, then the pairwise multiple comparison will determine which risk drivers are significantly different from the others. The original ranked data and tied data are shown in appendices D and E.

The test procedure and results are shown in tables 2, 3, and 4 below.

Table 2

Test Hypothesis for Performance Risk-Drivers

1. Null hypothesis (H_o)	The ten risk-driver candidates have no differential effect.
2. Alternative hypothesis (H_a)	At least one of the candidates tends to yield larger observed values than at least one other candidate.
3. Test statistics	$K^* = [\frac{12}{nk(k+1)} \sum_{j=1}^{k} R^2_{.j}] - 3n(k+1).$ Where $R_{.j} = \sum_{i=1}^{n} R_{ij}.$
4. Significance level	0.05
5. Critical values	$\chi^2_\alpha(k-1)=16.919$, where $\chi^2_\alpha(k-1)$ is the upper α percentile for a chi-square distribution with k-1 degrees of freedom.
6. Decision rule	Reject the null hypothesis if $K^* >= \chi^2_\alpha(k-1)$.
7. Test result	$K^*=83.845$ (7 respondents rated the risk to be low, and there are a total of 10 treatments, so, n=47 k=10), is greater than the critical value 16.919; therefore, the null hypothesis is rejected.

Table 3

Statistical Factors for Multiple Comparisons for Performance Risk-Drivers

1. Overall error rate	α=0.45. (10 treatments, k(k-1)/2=45 pairs).
2. Significance level for two-treatment comparison	α'=2*0.45/(10*9)=0.01. From Z table, $Z_{\alpha'/2}$=2.575
3. Significant difference interval	$\lvert R_{.j}-R_{.i}\rvert \geq Z_{\alpha'/2}\sqrt{\frac{nk(k+1)}{6}}$ $\lvert R_{.j}-R_{.i}\rvert$>=2.575*29.35,>=75.5

In table 3, a significant difference interval of 75.5 was found, which means that any two treatments with $R_{.j}$ values of more than 75.5 apart represent significantly different treatments.

Table 4

Test Result of Multiple Comparisons for Performance Risk-Drivers

Risk-driver candidate	Description	$R_{.j}$
7	Tight schedule for program implementation.	186.0
1	Requirements are not clearly and reasonably stated.	197.5
5	Technical problems cannot be resolved in a timely manner.	200.0
8	Poor program management in CSIST or ROCAF, or both.	206.5

Test Result of Multiple Comparisons for Performance Risk-Drivers (Cont)

6	Insufficient manpower to carry out the tasks.	230.5
2	Systems designed to an incomplete set of requirements.	271.0
4	Developmental testing performed independently by contractor and/or the TEMP implemented inappropriately or partially.	272.5
3	Inadequate configuration control.	287.5
9	Quality assurance isn't well planned or isn't carried out independently.	337.0
10	Others.	389.0

For the performance risk-drivers, statistically the following conclusions were drawn:

1. Tight schedule for program implementation (7) drives risk more than incomplete system design (2), inadequate configuration control (3), poor quality assurance (9), and others (10);

2. Ambiguous requirements (1), technical bottleneck (5), and poor program management (8) drive risk significantly than inadequate configuration control (3), poor quality assurance (9), and others (10);

3. No other differences are significant.

Supportability Risk. Investigative Questions 2. What is the magnitude of supportability risk in systems acquisition? What causes the risk?

A. What is the magnitude of supportability risk in systems acquisition? 53 respondents rated supportability risk. The summarized raw data is in appendix F, and the histogram (Figure 11) shows the magnitude of supportability risk.

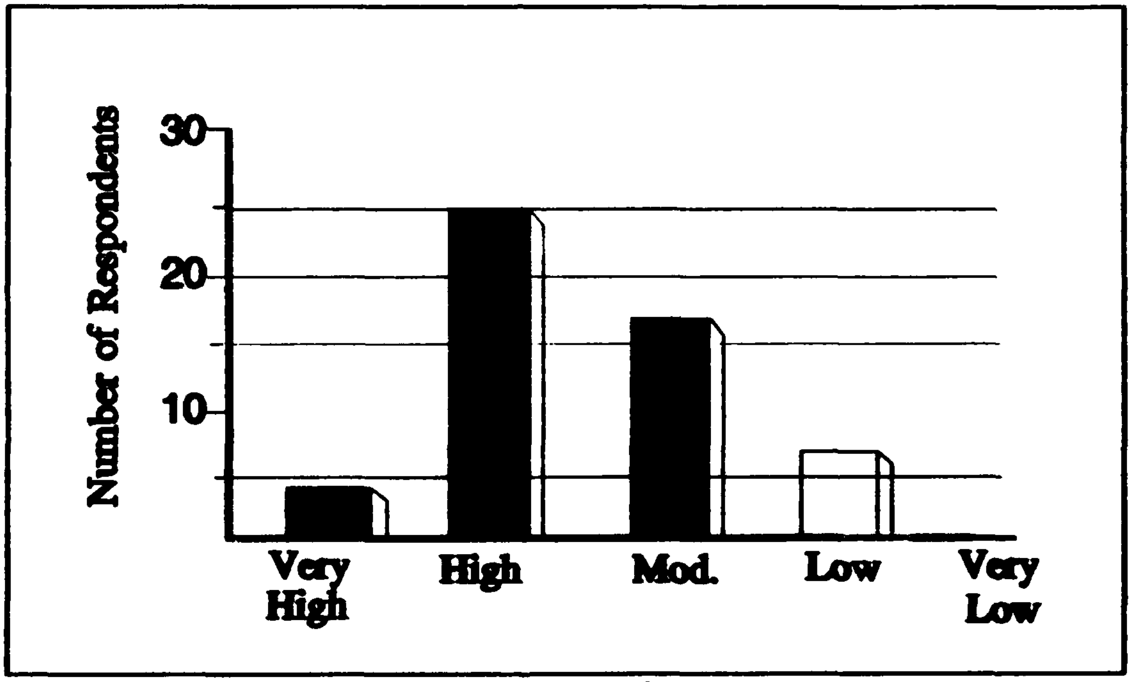


Figure 11. Supportability Risk

There are 4 out of the 53 respondents (7.6%) who rated the supportability risk in the current acquisition environment as Very High, 25 respondents (47.2%) as High, 17 respondents (32.0%) rated risk as Moderate, 7 respondents

(13.2%) as Low, and no respondents rated the magnitude of supportability risk as Very Low.

B. What causes the supportability risk? The original ranked data and tied data are shown in appendices G and H, respectively. The test results are shown in tables 5, 6, and 7 below.

Table 5

Test Hypothesis for Supportability Risk-Drivers

1. Null hypothesis (H_O)	The eleven risk-driver candidates have no differential effect.
2. Alternative hypothesis (H_a)	At least one of the candidates tends to yield larger observed values than at least one other candidate.
3. Test statistics	$K^* = [\frac{12}{nk(k+1)} \sum_{j=1}^{k} R^2_{.j}] - 3n(k+1)$. Where $R_{.j} = \sum_{i=1}^{n} R_{ij}$.
4. Significance level	0.05
5. Critical values	$\chi^2_\alpha(k-1)=18.3$, where $\chi^2_\alpha(k-1)$ is the upper α percentile for a chi-square distribution with k-1 degrees of freedom.
6. Decision rule	Reject the null hypothesis if $K^* >= \chi^2_\alpha(k-1)$.

Test Hypothesis for Supportability Risk-Drivers (Cont)

7. Test result	K^*=54.3 (7 respondents rated the risk to be low, and there are total 11 treatments, so, n=46 k=11), is greater than the critical value 18.3; therefore, the null hypothesis is rejected.

Table 6

Statistical Factors for Multiple Comparisons for Supportability Risk-Drivers

1. Overall error rate	α=0.55. (11 treatments, k(k-1)/2=55 pairs).
2. Significance level for two-treatment comparison	α'=2*0.55/(11*10)=0.01. From Z table, $Z_{\alpha'/2}$=2.575
3. Significant difference interval	$\lvert R_{.j}-R_{.i}\rvert \geq Z_{\alpha'/2}\sqrt{\frac{nk(k+1)}{6}}$ $\lvert R_{.j}-R_{.i}\rvert$>=2.575*31.82,>=81.9

In table 6, a significant difference interval of 81.9 was found, which means that any two treatments with $R_{.j}$ values of more than 81.9 apart represent significantly different treatments.

Table 7

Test Result of Multiple Comparisons for Supportability Risk-Drivers

Risk-driver candidate	Description	$R_{.j}$
8	Inexperienced and/or untrained personnel.	186.0
9	Tight schedule and insufficient manpower.	233.0
3	Manpower and skill analyses are based upon experience from previous system.	244.5
6	Spares are provisioned during the development phase(resulting in incompatibility with field requirements), or initial spares procured by part number without reference to the specification.	247.5
10	Poor program management in the CSIST or ROCAF, or both.	263.5
2	Logistics related design parameters are established after other performance parameters.	265.5
5	Training materials and equipment are developed based on initial training used for T&E personnel; which are not adequate for field use due to different skill levels, etc.	266.5
4	Requirements are not clearly and reasonably stated.	281.5
7	Technical manuals are written using the EMD LSA results which doesn't reflect the production configuration.	323.0
1	Contractor is given responsibility to develop the LSA program.	325.0
11	Others.	394.5

For the supportability risk-drivers, the following conclusions were drawn:

1. Inexperienced and/or untrained personnel (8) drives risk more than LSA developed by contractor (1), ambiguous requirements (4), unrealistic references to compile technical manuals (7), and others (11);

2. Tight schedule and insufficient manpower (9) drives risk more than LSA developed by contractor (1), unrealistic references to compile technical manuals (7), and others (11);

3. No other differences are significant.

Cost Risk. **Investigative Question 3.** What is the magnitude of life-cycle cost risk in systems acquisition? What causes the risk?

A. What is the magnitude of life-cycle cost risk in systems acquisition? 54 respondents rated life-cycle cost risk. The summarized raw data can be seen in appendix I, and the following histogram (Figure 12) shows the magnitude of life-cycle cost risk.

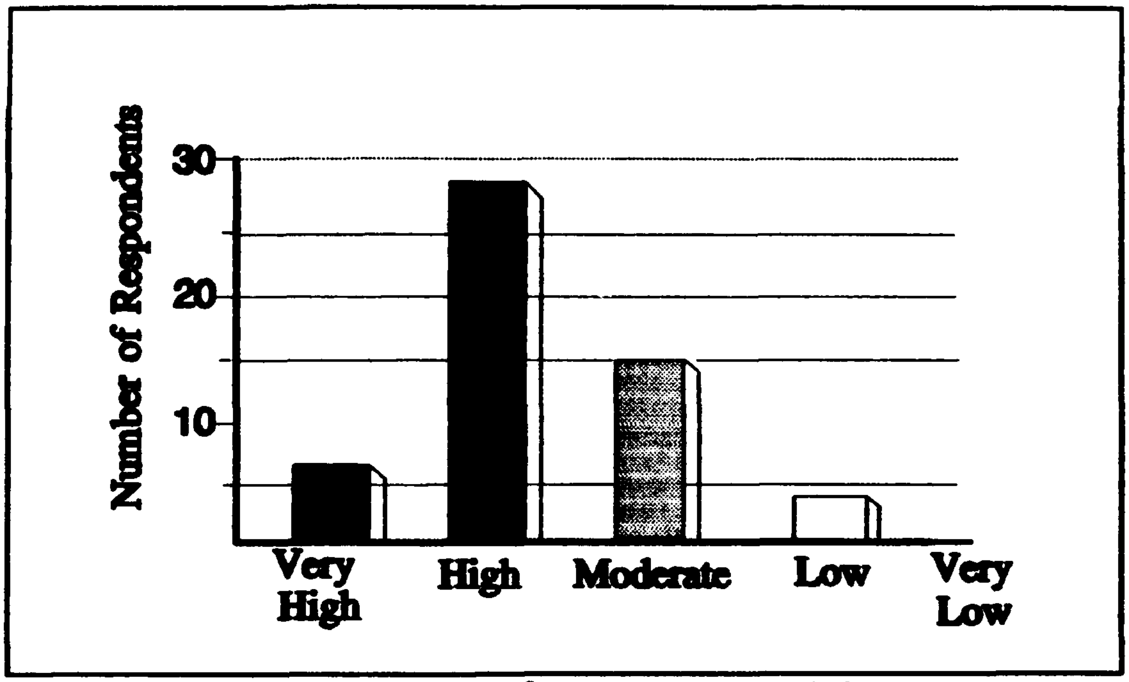


Figure 12. Life-Cycle Cost Risk

There are 7 out of the 54 respondents (12.9%) who rated the life-cycle cost risk in the current acquisition environment as Very High, 28 respondents (51.8%) rated it High, 15 respondents (27.8%) rated it Moderate, 4 respondents (7.5%) as Low, and no respondents rated the magnitude of life-cycle cost risk as Very Low. Notice that nearly 65% of the respondents rated life-cycle cost risk as High or Very High.

B. What causes the life-cycle cost risk? The original ranked data and tied data are shown in appendices J and K, respectively. The test results are shown in tables 8, 9, and 10 below.

Table 8

Test Hypothesis for Life-Cycle Cost Risk-Drivers

1. Null hypothesis (H_o)	The eight risk-driver candidates have no differential effect.
2. Alternative hypothesis (H_a)	At least one of the candidates tends to yield larger observed values than at least one other candidate.
3. Test statistics	$K^*=[\frac{12}{nk(k+1)}\sum_{j=1}^{k} R^2_{.j}]-3n(k+1).$ Where $R_{.j}=\sum_{i=1}^{n} R_{ij}.$
4. Significance level	0.05
5. Critical values	$\chi^2_\alpha(k-1)=14.06$, where $\chi^2_\alpha(k-1)$ is the upper α percentile for a chi-square distribution with k-1 degrees of freedom.
6. Decision rule	Reject the null hypothesis if $K^* >= \chi^2_\alpha(k-1)$.
7. Test result	$K^*=78.98$ (4 respondents rated the risk to be low, and there are total 8 treatments, so, n=50 k=8), is greater than the critical value 14.06; so, the null hypothesis is rejected.

Table 9

Statistical Factors for Multiple Comparisons for Life-Cycle Cost Risk-Drivers

1. Overall error rate	α=0.28. (8 treatments, k(k-1)/2=28 pairs).
2. Significance level for two-treatment comparison	α'=2*0.28/(8*7)=0.01. From Z table, $Z_{\alpha'/2}$=2.575
3. Significant difference interval	$\lvert R_{.j}-R_{.i}\rvert \geq Z_{\alpha'/2}\sqrt{\frac{nk(k+1)}{6}}$ $\lvert R_{.j}-R_{.i}\rvert$>=2.575*24.49,>=63.07

In table 9, a significant difference interval of 63.07 was found, which means that any two treatments with $R_{.j}$ values of more than 63.07 apart represent significantly different treatments.

Table 10

Test Result of Multiple Comparisons for Life-Cycle Cost Risk-Drivers

Risk-driver candidate	Description	$R_{.j}$
1	Ambiguous requirements or frequent requirement changes which cause major engineering changes and/or system redesigns.	143.5
5	Sole-source with no incentive to control cost overrun.	185.5
3	New technology is introduced without trade studies being fully conducted.	213.0

Test Result of Multiple Comparisons for Life-Cycle Cost Risk-Drivers (Cont)

2	Inadequate logistics related programming which results in a high maintenance burden.	213.5
6	Tight schedule and/or insufficient manpower.	219.0
7	Improper budget control system which result in a poor understanding of cost distribution.	232.5
4	Overall test program is not implemented appropriately, which results in rework or an increase in maintenance burden.	247.5
8	Others.	346.0

For the life-cycle cost risk-drivers, the following conclusions were drawn:

1. Ambiguous requirements or frequent requirement changes (1) drives risk significantly more than others drives except the sole source environment (5);

2. No other differences are significant.

Schedule Risk. **Investigative Question 4.** What is the magnitude of schedule risk in systems acquisition? What causes the risk?

A. What is the magnitude of schedule risk in systems acquisition? 53 respondents rated schedule risk. The summarized raw data can be seen in appendix L, and the following histogram (Figure 13) shows the magnitude of schedule risk.

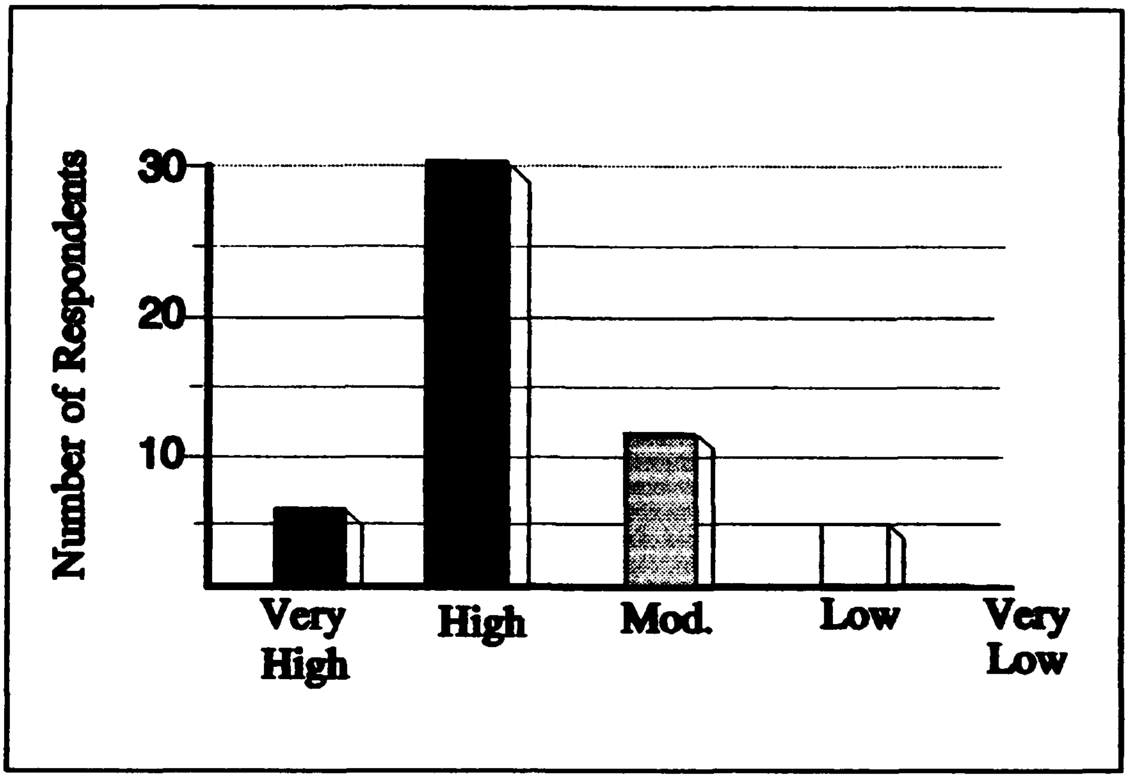


Figure 13. Schedule Risk

There are 6 out of the 53 respondents (11.3%) who rated the schedule risk in the current acquisition environment as Very High, 30 respondents (56.7%) as High, 12 respondents (22.6%) rated schedule risk Moderate, 5 respondents (9.4%) Low, and no respondents rated the magnitude of schedule risk as Very Low. Notice that 68% of respondents rated schedule risk as High or Very High.

B. **What causes the schedule risk?** The original ranked data and tied data are shown in appendices M and N, respectively. The test results are shown in tables 11, 12, and 13.

Table 11

Test Hypothesis for Schedule Risk-Drivers

1. Null hypothesis (H_o)	The nine risk-driver candidates have no differential effect.
2. Alternative hypothesis (H_a)	At least one of the candidates tends to yield larger observed values than at least one other candidate.
3. Test statistics	$K^{*}=[\frac{12}{nk(k+1)}\sum_{i=1}^{k}R^{2}_{.j}]-3n(k+1).$ Where $R_{.j}=\sum_{i=1}^{n}R_{ij}.$
4. Significance level	0.05
5. Critical values	$\chi^2_{\alpha}(k-1)=15.5$, where $\chi^2_{\alpha}(k-1)$ is the upper α percentile for a chi-square distribution with k-1 degrees of freedom.
6. Decision rule	Reject the null hypothesis if $K^{*} >= \chi^2_{\alpha}(k-1)$.
7. Test result	$K^{*}=62.78$ (5 respondents rated the risk to be low, and there are total 9 treatments, so, n=48 k=9), is greater than the critical value 15.5; so, the null hypothesis is rejected.

Table 12

Statistical Factors for Multiple Comparisons for Schedule Risk-Drivers.

1. Overall error rate	α=0.36. (9 treatments, k(k-1)/2=36 pairs).
2. Significance level for two-treatment comparison	$\alpha'=2*0.36/(9*8)=0.01$. From Z table, $Z_{\alpha'/2}=2.575$
3. Significant difference interval	$\lvert R_{.j}-R_{.i}\rvert \geq Z_{\alpha'/2}\sqrt{\frac{nk(k+1)}{6}}$ $\lvert R_{.j}-R_{.i}\rvert >= 2.575*26.83, >= 69.09$

In table 12, a significant difference interval of 69.09 was found, which means that any two treatments with $R_{.j}$ values of more than 69.09 apart represent significantly different treatments.

Table 13

Test Result of Multiple Comparisons for Schedule Risk-Drivers

Risk-driver candidate	Description	$R_{.j}$
1	Ambiguous requirements or frequent requirement changes which cause major engineering changes and/or system redesigns.	181.5
8	Late involvement of production and manufacturing engineering.	194.0
3	Poor subcontractor management.	205.5

Test Result of Multiple Comparisons for Schedule Risk-Drivers (Cont)

7	Tight schedule and insufficient manpower.	217.5
5	New technology is enforced without trade studies being fully conducted.	231.5
6	Overall test program is not implemented adequately or timely which results in system rework.	241.5
2	Poor configuration control.	254.5
4	Work Breakdown Structure has not been used to control individual projects and progress of system integration.	277.5
9	Others.	357.0

For the schedule risk-drivers, the following conclusions were drawn:

1. Ambiguous requirements or frequent requirement changes (1) drives risk significantly than poor configuration control (2), absence of using WBS to control projects (4) and others (9);

2. Late involvement of production and manufacturing engineering (8) and Poor subcontractor management (3) drive schedule risk significantly than absence of using WBS to control projects (4) and others (9);

3. No other differences are significant.

<u>Management Risk</u>. Investigative Question 5. What is the magnitude of management risk in systems acquisition? What causes the risk?

A. What is the magnitude of management risk in systems acquisition? 54 respondents rated management risk. The summarized raw data can be seen in appendix O, and the following histogram (Figure 14) presents the magnitude of the management risk.

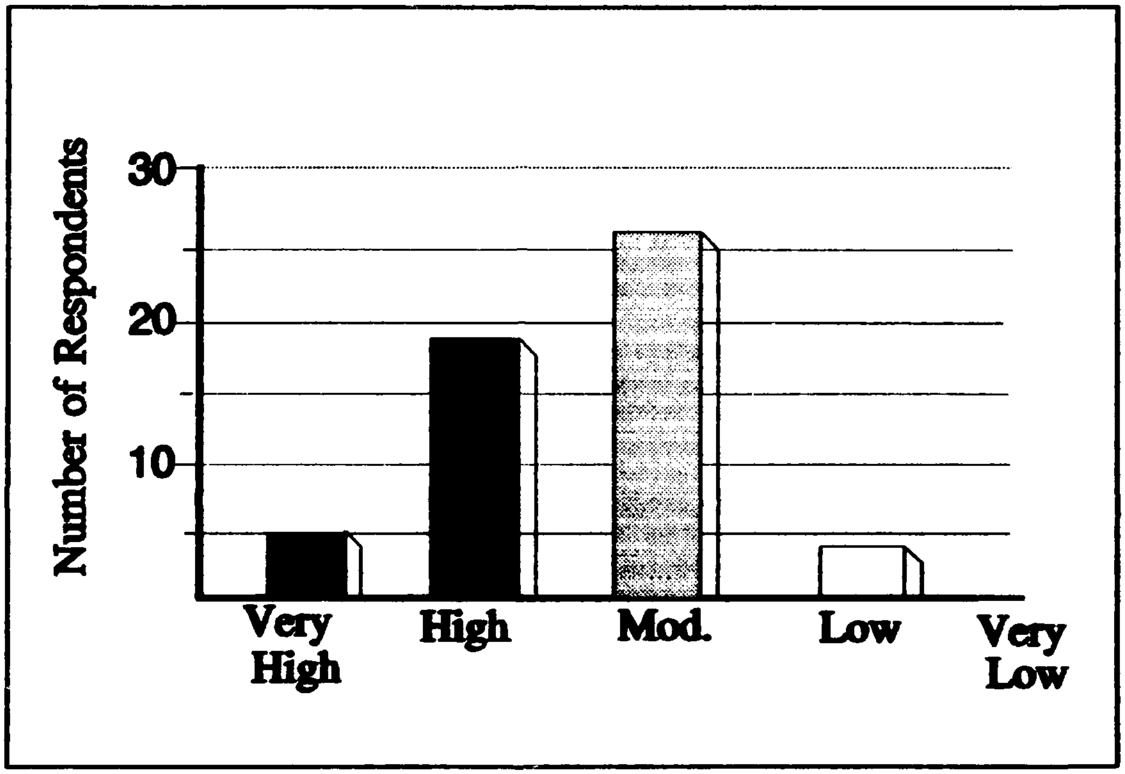


Figure 14. Management Risk

There are 5 out of the 54 respondents (9.3%) who rated the management risk in the current acquisition environment as Very High, 19 respondents (35.2%) rated it High, 26 respondents (48.1%) indicated the magnitude of management risk was Moderate, 4 respondents (7.4%) rated it Low, and no respondents indicated the magnitude of management risk was Very Low.

B. **What causes the management risk?** The original ranked data and tied data are shown in appendices P and Q, respectively. The test results are shown in tables 14, 15, and 16.

Table 14

Test Hypothesis for Management Risk-Drivers

1. Null hypothesis (H_o)	The eight risk-driver candidates have no differential effect.
2. Alternative hypothesis (H_a)	At least one of the candidates tends to yield larger observed values than at least one other candidate.
3. Test statistics	$$K^{*}=[\frac{12}{nk(k+1)}\sum_{j=1}^{k}R^{2}_{.j}]-3n(k+1).$$ Where $$R_{.j}=\sum_{i=1}^{n}R_{ij}.$$
4. Significance level	0.05
5. Critical values	$\chi^2_\alpha(k-1)=14.06$, where $\chi^2_\alpha(k-1)$ is the upper α percentile for a chi-square distribution with k-1 degrees of freedom.
6. Decision rule	Reject the null hypothesis if $K^{*} >= \chi^2_\alpha(k-1)$.

Test Hypothesis for Management Risk-Drivers (Cont)

7. Test result	K^*=30.1 (4 respondents rated the risk to be low, and there are total 8 treatments, so, n=50 k=8), is greater than the critical value 14.06; so, <u>the null hypothesis is rejected</u>.

Table 15

Statistical Factors for Multiple Comparisons for Management Risk-Drivers

1. Overall error rate	α=0.28. (8 treatments, k(k-1)/2=28 pairs).
2. Significance level for two-treatment comparison	α'=2*0.28/(8*7)=0.01. From Z table, $Z_{\alpha'/2}$=2.575
3. Significant difference-interval	$\lvert R_{.j}-R_{.i}\rvert \geq Z_{\alpha'/2}\sqrt{\frac{nk(k+1)}{6}}$ $\lvert R_{.j}-R_{.i}\rvert$>=2.575*24.49,>=63.07

In table 15, a significant difference interval of 63.07 was found, which means that any two treatments with $R_{.j}$ values of more than 63.07 apart represent significantly different treatments.

Table 16

Test Result of Multiple Comparisons for Management Risk-Drivers

Risk-driver candidate	Description	$R_{.j}$
5	CSIST and ROCAF lack mutual understanding of program objectives.	141.0
2	Ambiguous responsibility and authority defined among MND, ROCAF and CSIST.	173.5
1	Ambiguous requirements or frequent requirement changes which complicate program management.	189.0
6	Lack of relevant management skills and knowledge.	200.5
3	Risk management has not been conceived and integrated well into program management strategy.	218.5
4	Organizational problems such as providing limited career progression and promotion opportunities. ROCAF or/and CSIST suffering "brain-drain" problem.	266.5
7	Organizational problems such as bureaucracy, lack of/poor leadership, power struggles, etc.	274.5
8	Others.	332.5

For the Management risk-drivers, the following conclusion were drawn:

1. Lack of relevant management skills and knowledge (1) drives management risk significantly than inappropriate risk management plan (3), organizational problems--limited career progression, promotion opportunities, and "brain-

drain" (4), another organizational problems such as bureaucracy, lack of/poor leadership, power struggles (7), and others (8);

2. Ambiguous responsibility and authority defined among MND, ROCAF and CSIST is ranked significantly different from organizational problems--limited career progression, promotion opportunities, and "brain-drain" (4), another organizational problems such as bureaucracy, lack of/poor leadership, power struggles (7), and others (8);

3. No other differences are significant.

<u>Summary of The Additional Comments</u>

Respondents were asked to comment on the risk factors and their causes in part III of the questionnaire as a means of collecting additional research information. The comments are summarized and categorized by specific risk factor.

<u>A. Comments on Performance Risk</u>.

1. Systems engineers for both the CSIST and ROCAF (or services) need to be sufficiently trained. Systems integration is a great challenge in the current ROCAF acquisition environment.

2. Inputs for Mission Needs Statements and Operational Requirements Documents, such as, the overall national defense strategy, technologies and industrial capabilities, and so forth, should be realistic and well planned.

3. Adequate strategy for concurrence in development

and production, when it is considered to be desirable, should be well planned.

4. End users must be a part of the program from the very beginning.

5. Communications between the CSIST, MND and ROCAF need to be improved.

B. Comments on Supportability Risk.

1. Definitions for logistics requirements such as reliability, maintainability, systems safety, and so forth, need to be well stipulated, and the requirements should be carefully incorporated into systems designs.

2. The current status of field logistics should be considered when developing the integrated logistics plan.

3. Concurrence in development and production results in additional uncertainty for reliability, maintainability, and systems safety which, without proper care, will result in increasing supportability risk and operation and support costs.

4. Communications between the CSIST and ROCAF in terms of logistics requirements allocation need to improve to minimize risk magnitude.

C. Comments on Life-Cycle Cost Risk.

1. Cost risk is inevitable due to the lack of relevant experience in weapon systems designs, development, and production by the CSIST.

2. The CSIST has few incentives to control program costs since they are a sole-source provider and a government-owned organization. Business-like organizational changes should be considered for the CSIST.

3. Cost control is hampered by a lack of historical data for cost estimation. Therefore, the development of weapon systems cost information database is highly recommended.

D. Comments on Schedule Risk.

1. Critical systems technologies increase schedule risk if such technologies are not under the auspices of the CSIST.

2. Potentially, concurrence in development and production could increase the number of engineering changes, which is detrimental to schedule control. It is very important to prepare for the impacts of concurrence in advance and to adopt an appropriate acquisition strategy.

3. Detailed breakdowns of work are fundamental for successfully managing schedule and cost.

4. Political involvement should be minimized once the milestone decisions are made.

E. Comments on Management Risk.

1. Having "birds-eye view" of the program for high-level managers is critical to the success of the programs.

2. Subjective and objective program environments

should be considered thoroughly before determining the acquisition strategy.

3. The proper tour length for management personnel should be well defined.

4. The organizational culture, including the promotion system, leadership, authority, and responsibility need to be well defined in order to alleviate the frustration of engineers and managers.

Summary of Findings

Figure 15 illustrates the percentage of respondents who rated performance, supportability, life-cycle cost, schedule, and management high or very high risk. Notice that except management risk, more than 50% of respondents rated all other risk factors high or very high risk, in which schedule risk appears to be the most important risk, because nearly 70% of respondents rated it high or very high risk.

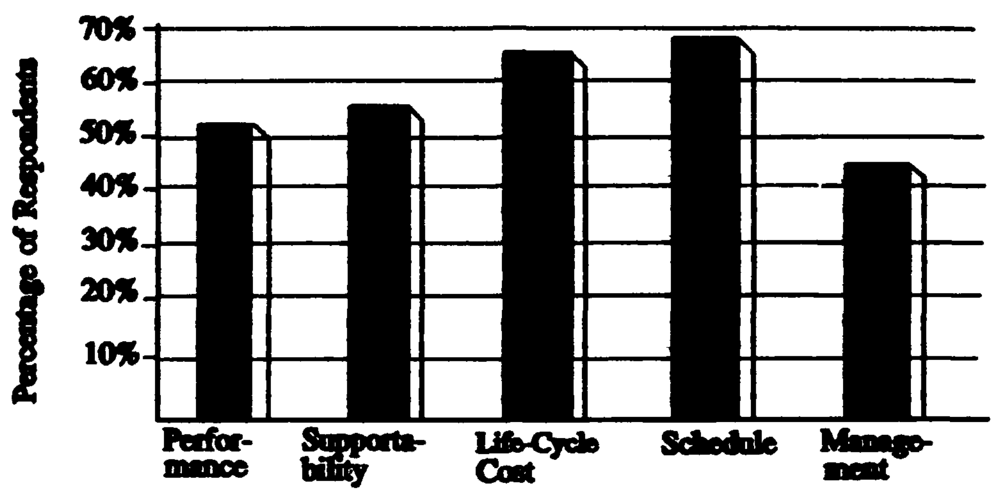


Figure 15. Percentage of Respondents Who Rated High or Very High Risk to the Five Risk Factors

Table 17 illustrates the risk magnitudes and drivers that were found in this chapter. Column 1 categorizes the risk factors; column 2 presents the mode responses for risk magnitude; and column 3 summarizes the most important risk drivers.

Table 17

Summarized Findings

Risk Factors	Risk Magnitude	Risk Drivers
Performance	High	. Schedule is too tight to implement required tasks effectively. . Requirements are not clearly and reasonably stated. . Technical bottlenecks exist, and are not exposed and solved in a timely manner. . Poor program management of the CSIST or the ROCAF, or both.
Supportability	High	. Inexperienced and/or untrained personnel are responsible for logistics planning and programming. . A tight schedule and a shortage of systems engineers for conducting the required logistics tasks.
Cost	High	. Ambiguous requirements or frequent requirement changes which result in major engineering changes and/or redesigns.

Summarized Findings (Cont)

Schedule	High	. Ambiguous requirements or frequent requirement changes which result in major engineering changes and/or redesigns. . Ineffective programming of systems integration resulting in major schedule deviations or late involvement of production and manufacturing engineering. . Poor subcontractor management.
Management	Moderate	. CSIST and ROCAF lack a mutual understanding of program objectives, which seriously complicates program management. . Ambiguous lines of responsibility and authority defined between the MND, ROCAF and CSIST.

Recall from figure 8 that the magnitudes of the risk factors were measured by the respondents, a majority of whom declared a risk propensity of risk neutral with a few risk avoiders. However, the risk-neutral propensity of the respondents reveals that the rated risk magnitudes for those factors are probably accurate. It is also possible the risk magnitudes responded in this study are slightly overestimated since 37% of the respondents are risk averse.

The result of self-evaluation of management competency by the respondents also warrant discussion. Nearly 89% of respondents indicated they are competent in their day-to-day management, and do not request any additional managerial training. This contrasts with results of the survey conducted at Wright-Patterson Air Force Base in 1989 where ASD managers requested more training for competency (4:97). According to Edwards W. Deming, the American who taught the Japanese about quality, quality is the responsibility of management (33:116-7), and in fact Deming asserts that most troubles and most possibilities for improvement add up to proportions of 94% belongs to management responsibility (36 :315). In this study the perceived risk associated with management was lower than all other categories. Since the survey sample included only mid-to-high level managers, the results of this study suggests the managers may be underestimating the extent to which management is contributing to risk in ROCAF system acquisition management.

Program managers must be the primary agents for improvement (33:182). In fact, management should assume responsibility for two management risk-drivers that were identified. First, the CSIST and ROCAF both lack a mutual understandings of program objectives. Second, ambiguous lines of responsibility and authority defined between the MND, ROCAF and CSIST.

Summary

This chapter has examined the acquired data according to the methodologies introduced in chapter III, and has achieved the research objectives stated in the chapter I. The first objective was to explore the magnitude of potential major risks in terms of performance, cost, schedule, management, and supportability in the ROCAF's major systems acquisition process. The second objective was to identify and understand risk-drivers in the ROCAF weapon systems acquisition process. Chapter V presents the conclusions and recommendations of the research.

V. Conclusions and Recommendations

Overview

This chapter will provide the conclusions of this research. It will then address some recommendations proposed by the researcher to mitigate the risks perceived by the respondents in the ROCAF's weapon systems acquisition. Finally, this chapter will present some recommendations for future studies.

Conclusions

This study determined that the risks of performance, supportability, cost, and schedule are high, and management risk is moderate. Risk magnitude refers to the combination of probability of occurrence of an unwanted outcome and the severity of impact. High risk means that this combination is more than likely to happen. Since resources are limited, management should be aware of risks and endeavor to alleviate the associated impacts. Although it is known that cost, schedule, supportability, and performance risks are often related and result from the same risk drivers, two risk drivers actually resulted in high risk for more than one risk-factor in the ROCAF's acquisitions. Management efforts should be concentrated on these two drivers accordin.ly The multi-dimensional drivers are:

A. Ambiguous requirements or frequent requirement changes drive performance, life-cycle cost, and schedule risks of the ROCAF acquisition.

B. Tight program schedules caused by the need for rapid systems deployment contribute to both performance and supportability risks.

Frequently it is very difficult to mitigate risks which result from external factors. This is the case with the second risk driver-tight schedules, because the schedules are typically policy driven.

Analogy to U.S. Acquisition Problems

Notwithstanding the numerous defense programs which have been completed in the U.S., many researchers and presidential commissions have concluded repeatedly that opportunities exist to save billions of dollars by improving the acquisition process. The studies repeatedly urged Congress and the DoD to correct five basic deficiencies which are similar to those reported in chapter IV, namely:

A. Unrealistic requirements for the most sophisticated systems attainable, often irrespective of cost;

B. Underestimated schedules and costs of major programs, which distort the decision-making process for the allocation of the national budget;

C. Changes in program and contract requirements caused by changes in military user preferences, leading to annual or more frequent changes in program funding levels, initiated by either Congress or the DoD itself;

D. Lack of incentives for contractors and government personnel to reduce program costs; and

E. Failure to develop sufficient numbers of military and civilian personnel with training and experience in business management and in dealing with industrial firms to oversee the development and production of enormous, highly technical industrial programs (35:32).

Recommendations

As indicated previously, the purpose of risk identification is to mitigate the risks. The following recommendations are made to assist the ROCAF acquisition process and are based on comments from the survey respondents. The recommendations are organized according to the identified risk drivers in the following tables (18-22).

Table 18

Recommendations for Mitigating Performance Risk

Identified Risk Drivers	Recommendations
A. Tight schedule to implement required tasks effectively.	A.1. Defense discrepancies and mission needs should be identified accurately in a timely manner. The resolution of this problem requires constant review efforts. A.2. The acquisition strategy should address schedule constraints. Concurrent engineering is recommended.

Recommendations for Mitigating Performance Risk (Cont)

Identified Risk Drivers	Recommendations
B. Requirements are not clearly and reasonably stated.	B.1. Employ a consultant company to help prepare clear requirements documents when the in-house capability hasn't yet been established. B.2. Communicate with the CSIST to assure a clear understanding of the requirements. B.3. Comprehend state-of-the-art and advanced technologies would help define requirements. B.4. Establish a technology information library.
C. Technical bottlenecks exist and aren't identified in a timely manner.	C.1. The Dem/Val phase of the program should be retained since it helps to isolate technical bottlenecks. C.2. The application of concurrent engineering could detect technical pitfalls in the various phases.
D. Poor program management in the CSIST, or the ROCAF, or both.	D. Appropriate personnel training is required. The National Defense Management College should expand its educational programs or offer professional continuing education for systems management.

Table 19

Recommendations for Mitigating Supportability Risk

Identified Risk Drivers	Recommendations
A. Inexperienced and/or untrained personnel are responsible for logistics planning and programming.	A.1. Employ a consultant company to support the logistics planning and programming. A.2. Appropriate personnel training is required. The National Defense Management College should expand its educational programs or offer the professional continuing education for systems management. A.3. In addition to the traditional training programs, coaching and mentoring are also good ways of developing competent personnel.
B. Tight schedules and a shortage of systems engineers for conducting the required logistics tasks.	B.1. The acquisition strategy should address schedule constraints. Concurrent engineering is recommended. B.2. Manpower shortages can be resolved in two ways: B.2.a. Systems engineers for logistics should be trained. B.2.b. To minimize the "brain-drain" problem in both the CSIST and ROCAF, the organizational cultures including the promotion system, leadership, authority, and responsibility; need to be well defined and cultivated in order to minimize the frustration of engineers and managers.

Table 20

Recommendations for Mitigating Life-Cycle Cost Risk

Identified Risk Drivers	**Recommendations**
A. Ambiguous requirements or frequent requirement changes which result in major engineering changes and/or redesigns.	**A.1.** To resolve the ambiguous requirements, the ROCAF can: **A.1.a.** Use a consultant company to help define clear requirements. **A.1.b.** Communicate with the CSIST to assure a clear understanding of the requirements. **A.2.** It is important to understand that requirements will change to coincide with changes of the threats. Nonetheless, in order to alleviate the impacts of the changes, systems design should consider appropriate flexibility for requirements changes. **A.3.** Concurrent engineering can be used to determine and minimize the impacts of requirement changes.

Table 21

Recommendations for Mitigating Schedule Risk

Identified Risk Drivers	**Recommendations**
A. Ambiguous requirements or frequent requirement changes which result in major engineering changes and/or redesigns.	**A.** See the recommendations for Life-Cycle Cost Risk.

Recommendations for Mitigating Schedule Risk (Cont)

Identified Risk Drivers	Recommendations
B. Ineffective systems integration which causes complicated schedule control or late involvement of production and manufacturing engineering which increases schedule risk.	B.1. Good systems integration calls for well trained systems engineers. More systems engineers should be trained. B.2. Create motivation to minimize the "brain drain" from the CSIST and ROCAF. B.3. A consultant company can be used to help systems integration. B.4. Concurrent engineering can be adopted to introduce early involvement of production and manufacturing engineering.
C. Poor subcontractor management.	C.1. Statements of Work should be clearly defined to stipulate all non-specification requirements for contractor efforts either directly or with the use of specific cited documents. C.2. Many techniques such as Cost/Schedule Control System Criteria (C/SCSC), Technical Performance Measurement (TPM), and Program Evaluation Review Technique (PERT) can be used. According to the questionnaires, these techniques are not currently being used extensively with the exception of Work Breakdown Structures (WBS).

Table 22

Recommendations for Mitigating Management Risk

Identified Risk Drivers	Recommendations
A. Lack of mutual understanding on program objectives and management between the CSIST and ROCAF.	A.1. Make the defense programs more business-like to build mutual understanding since, by definition, the current differences between the organizational goals introduce conflicts in program management. A.2. More detailed defense acquisition regulations defining responsibilities, authorities, and accountabilities should be instituted.
B. Ambiguous lines of responsibility and authority defined between the MND, ROCAF and CSIST. Currently, this ambiguity causes severe impacts to the programs and their management.	B. Same as for A.

Complementary Recommendations

For day-to-day program management, the DSMC suggests that the application of the "Transition from Development to Production" templates and the "Best Practices" guide should reduce many program risks. The risk drivers are almost identical to the "traps" and "areas of risk" suggested by these publications, hence both could prove to be invaluable tools to ROCAF weapons acquisition management.

A careful review of the recommendations stated previously shows that increasing systems-engineering manpower and applying concurrent engineering are important strategies to confront the diverse performance, supportability, life-cycle cost, and schedule risks for the following reasons:

A. Systems engineers for both the CSIST and ROCAF should be trained as suggested in this study. These engineers can help to analyze, translate and allocate requirements into specifications as well as anticipate program traps in terms of technology insertion and systems integration.

B. According to the comments from the respondents, an adequate strategy for managing concurrency of phases due to the demands of faster product delivery should be well planned. This problem cannot be overcome without competent systems engineers.

C. Concurrent engineering is defined as

> a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause the developers, from the onset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements (29:18).

Concurrent engineering is a relatively recent time-based management innovation directed to shortening the product or service development (32:7) and might enhance product quality if the challenges of its application can be overcome.

The framework for application of concurrent engineering is shown in figure 16.

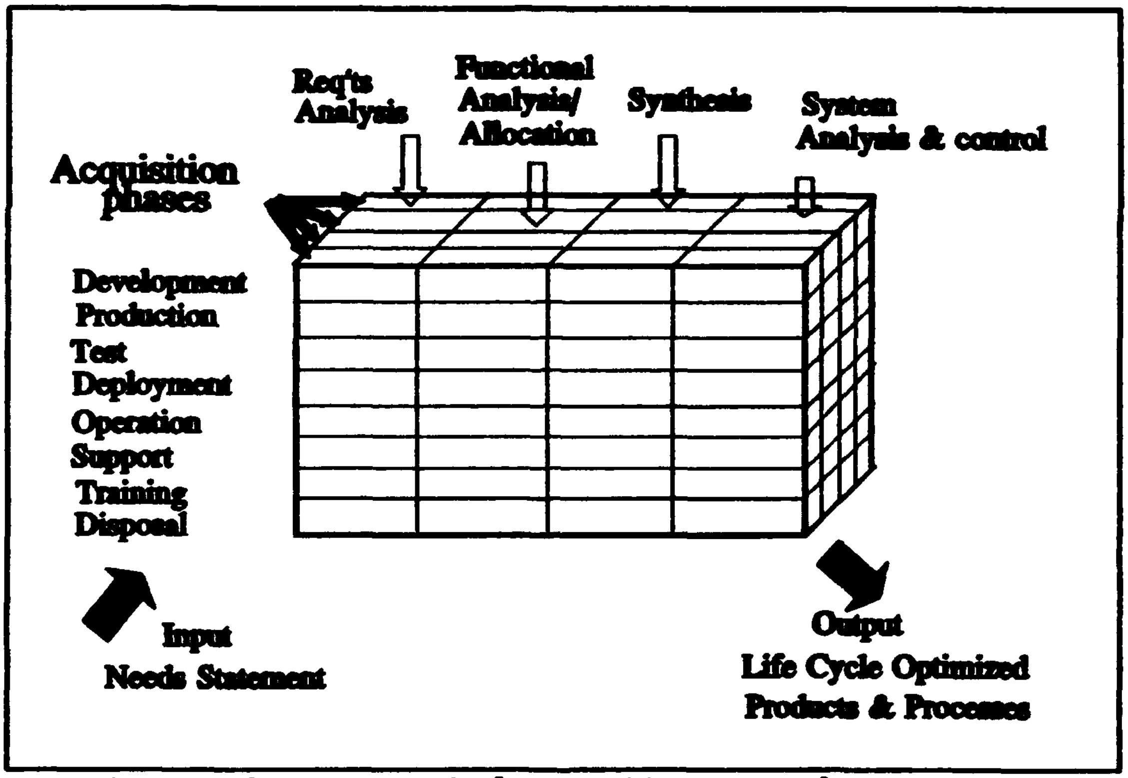


Figure 16. Framework for Application of Concurrent Engineering (29:19)

The challenges of implementing concurrent engineering, according to Program Manager, a DSMC publication, were: organizational structures, business practices, funding and budgeting for concurrent engineering, education, integration of cost, schedule, performance and risk (29:20).

Ten problems related to overcoming these challenges were identified by the DoD in 1990 in which lack of universal understanding of the philosophy, processes, tools and practices of concurrent engineering was the major problem (29:20). Five solutions were suggested by the DoD concurrent engineering workshop, which also can be used to the ROCAF and other services acquisition management:

A. Top management support for concurrent engineering education.

B. Educate the DoD and industry infrastructures in concurrent engineering education.

C. Establish concurrent engineering education opportunities.

D. Design curricula for concurrent engineering.

E. Dialogue within and among constituencies on conc ent engineering (29:22-3).

Notice that the accomplishment of concurrent engineering calls for integration of diverse disciplines. Normally systems engineers will act as integrators to assure the success of its application. This further highlights the importance of the first recommendation stated previously, i.e, systems engineers for both the CSIST and ROCAF should be trained sufficiently. Establishment of this training program should be given precedence in order to minimize risks in ROCAF's weapon systems acquisitions.

Recommendations for Future Studies

Since this research was a pilot study of ROCAF weapon systems acquisition risk, its scope of research is limited to risk identification. Since risk identification is only a part of risk management which ultimately requires risk handling, there are many areas that have not been covered in this research which should be studied, such as:

A. This study did not identify that CSIST, a government-owned and nonprofit organization, was a statistically significant cost risk driver. However, the status of the CSIST shows that it is still an important driver. Technical study should be conducted to investigate how a government-owned or nonprofit organization can be incentivized to control program expenses. When this study is completed, it can be used as a reference for considering the organizational changes of such organizations.

B. Since resource constraints, such as the manpower shortage in the Weapon Systems Acquisition Management Office (WSAMO), a newly-activated office in the ROCAF general headquarters, determine the likelihood of inherent risks in weapon acquisitions, research should be conducted to analyze cost/benefit trade-offs study associated with integrating the ROCAF and CSIST manpower and centralizing program management.

C. Acceptable risk has been reviewed briefly in chapter II and will vary on a case by case basis. However, for each acquisition activity in which the subjective and objective acquisition environments are different, it would be useful to conduct a study guiding overall considerations for acceptable risk of the ROCAF and other services' acquisition environment.

Appendix A: Questionnaire for Risk Identification in Major Weapon Systems Acquisition in the ROCAF (English)

Purpose

To identify the risk areas and their drivers in major weapon systems acquisition in the ROCAF from which a universal understanding of effective program management can be made.

Justification

For the defense programs that are undergoing certain constraints in the ROCAF, it's desired to understand the subjective and objective environments and how those environments, or constraints, affect the weapon systems acquisition prior to program implementation. From the study, an awareness of the likelihood of occurrence of unwanted outcomes of programs can be determined and remedial actions can be taken accordingly. It is important to emphasize that the purpose of this survey is not to review particular defense projects, but rather to learn the constraints and the means for dealing with them.

Method

Risk Assessment is dependent upon one's insight. The Expert Interview (survey) is considered the most appropriate of the methods suggested by the U.S. Defense System Management College in terms of reaching the research objectives as well as the goal stated in the previous paragraph.

Sampling

Since the population of defense program managers is relatively small, and also since the IDF program receives a great deal of the defense budget and manpower, those mid-to-high level managers in the IDF program, in both the ROCAF and CSIST, are considered to be the most capable program managers currently in the defense acquisition process. To survey those managers is, therefore, considered an unbiased estimation technique for the causation and magnitudes of the acquisition risks.

Anonymity

The disclosure of your name and/or position is absolutely optional. In order to secure the content validity of the research, each questionnaire will be sealed in an envelop and, the confidentiality of your responses is guaranteed. If you choose to print your name and/or position this information will be considered when the author conducts the statistical analysis. However, weighting is also based upon the answer given during the self-appraisal question in the first questionnaire and upon the author's discretion.

Response Guide

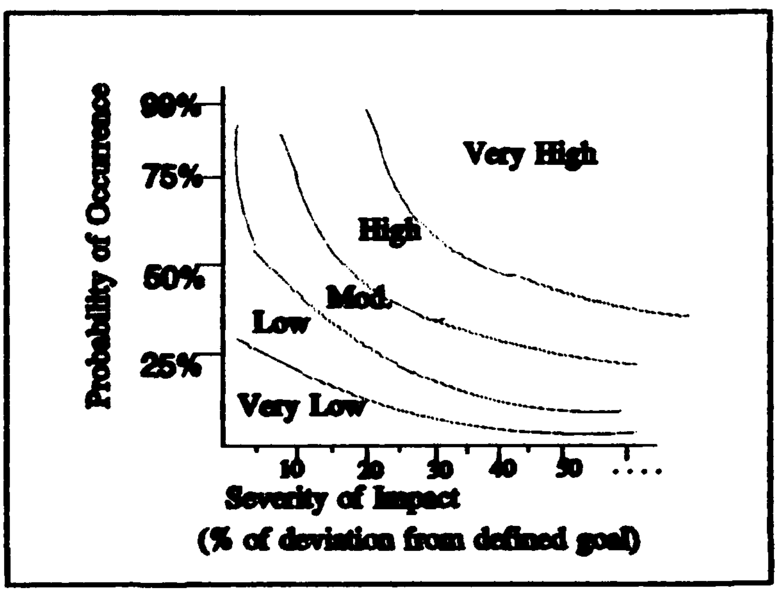
A. The questionnaire is segmented into three parts for each question. You will be asked to answer at least the first two **ACCORDING TO YOUR OWN OPINIONS**. The first part concerns the magnitude of the performance, supportability, cost, schedule and management risk. The second part concerns risk causation. You are also invited to comment on any other aspects of weapon systems acquisition.

B. Before choosing your answer, it's recommended that you preview the question and all possible choices.

C. For the first part of the question, choose only one answer from the list.

D. For the second part, either choose and prioritize your answer from the list provided or write-in your own answer in the space provided.

E. Magnitude of risk is somewhat qualitative and subjective; however, it is requested that you attempt to quantify the magnitude of the risk in terms of probability amount (that is, 1%, 34%, 50%, 68%,...., etc.) before selecting a "preference" for that particular question. The



figure[1] provides an overall picture for rating the magnitude of risk. For example, a 70% probability of occurrence accompanied with 5% severity of impact (determined by you) would be considered low risk, whereas 20% probability of occurrence with 40% severity of impact would be considered moderate risk.

Risk Management Concept and Guidance:4-9

Questionnaire about Yourself

Feb 10 1992

A. Name (optional)

B. Service and Position (optional)

C. Years in the program (to one decimal place)

D. Is your current job mostly managerial or technical (check one)

M----- E-----

E. Familiarity of weapon systems acquisition process and its management (check one)

1. Highly competent ------- (If you feel your day-to-day management and decision-making are very easy)

2. Competent ------- (If you feel your day-to-day management and decision-making are easy and give you very few problems.)

3. Moderate ------- (If you feel your day-to day management and decision-making are somewhat difficult, but everyone has the same management problem.)

4. More improvement needed ------ (If you feel your day-to-day management and decision-making are difficult and cause you problems, but that additional training would improve the situation)

5. Unqualified ------ (If you feel your day-to-day management and decision-making is very difficult and that no amount of additional training would improve the situation)

(continued on next page)

F. Concerning your personal propensity for risk taking in your day-to-day life, are you

A Risk Taker _____ Risk Neutral _____ A Risk Avoider ____

(Example: you might rate yourself as a risk taker if you always speculate in stocks.)

G. Are you aware of any risk management techniques available to you (such as the Work Breakdown Structure, Cost/Schedule Control System Criteria (C/SCSC), Technical Performance Measurement (TPM), Venture Evaluation Review Technique (VERT), Program Evaluation Review Technique (PERT), etc.)

Yes ______ Somewhat ______ No ______

(If your answer for question G is Yes, please continue with question H, otherwise continue to the next page)

H. Do you use risk management techniques in your program?

Yes ______ Somewhat ______ No ______

Questionnaire for Performance Risk Identionfication

Part 1. Based on your experiences and understanding, if current acquisition variables (resource availability, policies,etc.) remain unchanged, how will it affect performance risk in major defense systems?

(Definition of performance risk: Likelihood that defined operational effectiveness such as maneuverability, durability, and Pilot Vehicle Interface will not be achieved. Note, these do NOT include suitability.)

(Please check one)

Very high	High	Moderate	Low	Very Low
-----	-----	-----	-----	-----

Part 2. If your answer in Part 1 was Moderate, High, or Very High, please rank the candidate(s) which is (are) the likely risk driver(s) from the list below. You may check as many candidates as you wish using the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 where 1 represents the most critical driver and 9 represents the least critical diver. Do not answer this question if your answer in Part 1 was Low or Very Low.

EXAMPLE: (3) 1.***************
(2) 2.***************

(   ) 1. Requirements are not clearly and reasonably stated[1].

(   ) 2. Systems design analysis is not carefully conducted. In other words, the system is designed to an incomplete set of requirements

(   ) 3. Bad configuration control.

(   ) 4. Developmental testing is independently performed by the contractor and/or the Test and Evaluation Master Plan is not implemented appropriately and thoroughly.

(   ) 5. Technical problems can not be resolved in a timely manner.

(   ) 6. Insufficient manpower to carry out the tasks.

---

[1] Most of candidate drivers were taken from the Best Practices and DoD 4245.7-M--Transition from Development to Production.

(   ) 7. Tight schedule to implement the tasks sufficiently.

(   ) 8. Poor program management in CSIST or ROCAF, or both.

(   ) 9. Others. (Please state below).

Others:

Part 3. Additional Comments: (Your comments on performance risk or management are solicited. Please use the back side if necessary.)

Questionnaire for Supportability Risk Identification

Part 1. Based on your experiences and understanding, if current acquisition variables (resource availability, policies,etc.) remain unchanged, how will it affect supportability risk in major defense systems?

(Definition of supportability risk: Likelihood that defined suitability such as supportability, reliability, maintainability, system safety will not be achieved.)

(Please check one)

Very High	High	Moderate	Low	Very Low
-----	-----	-----	-----	-----

Part 2. If your answer in Part 1 was Moderate, High, or Very High, please rank the candidate(s) which is (are) likely the risk driver(s) from the list below. You may check as many candidates as you wish using the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 ,10, 11 where 1 represents the most critical driver and 11 represents the least critical diver. Do not answer this question if your answer in Part 1 was Low or Very Low.

EXAMPLE: (3) 1.***************
(2) 2.***************

( ) 1. Contractor is given responsibility to develop the Logistics Support Analysis program.

( ) 2. Logistics related design parameters are established after other performance parameters.

( ) 3. Manpower and skill analyses are based on experience from previous systems.

( ) 4. Ambiguous and or unreasonable requirements.

( ) 5. Training materials and equipment are developed based on initial training used for Test and Evaluation personnel; which are not adequate for field use due to different skill levels, etc.

( ) 6. Spares are provisioned during the development phase (resulting in incompatibility with field requirements), or initial spares procured by part number without reference to the specification (increased maintenance burden).

( ) 7. Technical manuals are written using the EMD logistics support analysis results which do not reflect the production configuration.

( ) 8. Inexperienced and/or untrained personnel.

( ) 9. Tight schedule and insufficient manpower to implement the relevant tasks.

( ) 10. Poor program management.

( ) 11. Others. (Please state below).

Others:

Part 3. Additional Comments: (Your comments on supportability risk or management are solicited. Please use the back side if necessary.)

Questionnaire for Life-Cycle Cost Risk Identification

Part 1. Based on your experiences and understanding, if current acquisition variables (resource availability, policies,etc.) remain unchanged, how will it affect life-cycle cost risk in major defense systems?

(Definition of life-cycle cost risk: Likelihood of budget overrun during system life-cycle period.)

(Please check one)

Very High	High	Moderate	Low	Very Low
-----	-----	-----	-----	-----

Part 2. If your answer in Part 1 was Moderate, High, or Very High, please rank the candidate(s) which is (are) likely the risk driver(s) from the list below. You may check as many candidates as you wish using the numbers 1, 2, 3, 4, 5, 6, 7, 8 where 1 represents the most critical driver and 8 represents the least critical diver. Do not answer this question if your answer in Part 1 was Low or Very Low.

EXAMPLE: (3) 1.***************
(2) 2.***************

(   ) 1. Ambiguous requirements or frequent requirement changes which cause major engineering changes and/or redesigns.

(   ) 2. Inadequate Logistics related programming which results in a high maintenance burden.

(   ) 3. New technology is introduced without trade studies being fully conducted.

(   ) 4. Overall test program is not implemented appropriately which results in rework or an increase in maintenance burden.

(   ) 5. Sole-source with no incentive to control cost overrun for the program or poor cost management/control techniques.

(   ) 6. Tight schedule and insufficient manpower to implement the relevant tasks.

(   ) 7. Improper budget control system which results in a poor understanding of the cost distribution.

(   ) 8. Others. (Please state below).

Others:

Part 3. Additional Comments: (Your comments on life-cycle-cost risk or management are solicited. Please use the back side if necessary.)

Questionnaire for Schedule Risk Identification

Part 1. Based on your experiences and understanding, if current acquisition variables (resource availability, policies,etc.) remain unchanged, how will it affect schedule risk in major defense systems?

(Definition of schedule risk: Likelihood of late product delivery.)

(Please check one)

Very High ----- High ----- Moderate ----- Low ----- Very Low -----

Part 2. If your answer in Part 1 was Moderate, High, or Very High, please rank the candidate(s) which is (are) likely the risk driver(s) from the list below. You may check as many candidates as you wish using the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 where 1 represents the most critical driver and 9 represents the least critical diver. Do not answer this question if your answer in Part 1 was Low or Very Low.

EXAMPLE: (3) 1.***************
(2) 2.***************

( ) 1. Ambiguous requirements or requirements changed frequently which cause major engineering changes and/or redesigns.

( ) 2. Poor configuration control.

( ) 3. Poor subcontractor management.

( ) 4. Work Breakdown Structure is not being used to control the individual projects and the integration progress.

( ) 5. New technology is introduced without trade-off studies, or technical barriers impedance.

( ) 6. Overall test program is not implemented appropriately or timely which results in rework.

( ) 7. Tight schedule and insufficient manpower to implement the relevant tasks properly.

( ) 8. Late involvement of production and manufacturing engineering.

(   ) 9. Others. (Please state below).

Others:

Part 3. Additional Comments: (Your comments on schedule risk or management are solicited. Please use the back side if necessary.)

Questionnaire for Management Risk Identification

Part 1. Based on your experiences and understanding, if current acquisition variables (resource availability, policies,etc.) remain unchanged, how will it affect management risk in major defense systems?

(Definition of management risk: Likelihood of instability and problems with program management.)

(Please check one)

Very High	High	Moderate	Low	Very Low
-----	-----	-----	-----	-----

Part 2. If your answer in Part 1 was Moderate, High, or Very High, please rank the candidate(s) which is (are) likely the risk driver(s) from the list below. You may check as many candidates as you wish using the numbers 1, 2, 3, 4, 5, 6, 7, 8 where 1 represents the most critical driver and 8 represents the least critical diver. Do not answer this question if your answer in Part 1 was Low or Very Low.

EXAMPLE: (3) 1.***************
(2) 2.***************

( ) 1. Ambiguous requirements or frequent requirement changes which severely complicate program management.

( ) 2. Ambiguous lines of responsibility and authority defined between the ROCAF, MND and CSIST.

( ) 3. Risk management plan has not been conceived and integrated into the program management strategy.

( ) 4. No advanced planning given for career progressions or promotional opportunities.

( ) 5. Industry and users (or SPOs) have no mutual understanding of program objectives and its management, which seriously complicates program management.

( ) 6. Lack of relevant management skills and knowledge.

( ) 7. Organizational problems such as bureaucracy, lack of/poor leadership, power struggles, etc.

( ) 8. Others. (Please state below).

Others:

Part 3. Additional Comments: (Your comments on management risk are solicited. Please use the back side if necessary.)

Appendix B:空軍武器系統獲得風險研究問卷調查表

目　　的：掌握並瞭解目前空軍主要武器獲得之風險範疇、風險程度及造成風險原因，藉以建立管理階層之共識，俾落實計劃之管理。

說　　明：基於我國大力推動國防自主，強化國防力量之際，期於個別計劃進展之前或同時，能對於主、客觀環境因素所可能造成之計劃風險程度及其有關因素，作一通盤性之瞭解。本項研究無特定之計劃對象，旨在瞭解主、客觀限制因素所可能造成之風險程度後，或可在適當時機研擬解決瓶頸辦法，以增計劃之成功率。

調查方式：依美『國防系統管理學院』出版"風險評估指導"所列之調查方式中，對管理階層人員進行問卷調查(EXPERT INTERVIEWS)為最符合上項目的及說明欄所述者之調查方式。基於風險評估及依個人觀點而不同，經蒐集中、高階層管理人員之各方意見加以統計分析後，可獲致較具代表性之結論。

抽樣方法：由於我國空軍主要武器裝備獲得(自主研製)依國防政策係由中山科學研究院主其成，至今完成或進行中之計劃尚有限；故而全體(POPULATION)之管理人員數量亦屬有限(非屬無限大)。故擬採儘量 "全體" 涵蓋之方式，唯因時空因素所限，不擬對陸、海軍計劃管理人員進行採樣問卷，僅針對國防部、空軍及中科院(航發中心)中、高管理階層進行問卷調查，所抽樣數量考量目前 "全體" 數之比例前題下，應屬具代表性之問卷調查。

問卷回覆方法及有關事宜：

一、有關具名回覆與否：

為確保覆卷內容之代表性起見，本問卷採密封式回覆，至於問卷欄上是否填具姓名完全取決於個人自由，唯筆者將依答卷人之職務、經驗等資料於進行統計分析時，視情況對覆卷長官之覆卷內容加權。

二、覆卷事宜：

㈠本問卷分叁大部份，覆卷時請獨立作業。

第一部份—針對計劃之性能、支援度、成本及時程與管理五項之風險程度依當前主、客觀因素做一判斷。

第二部份—針對第一部份之風險問題列選其可能造成風險之因素。

第三部份—則為自由意見欄：本部份旨在收集各長官對特定項目之意見，如無意見可省略本部份。

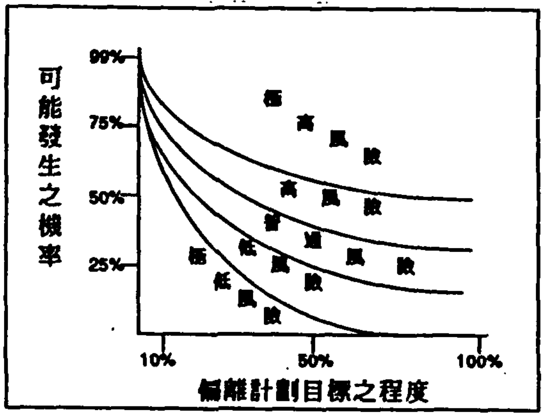
㈡於覆卷前，建議先行綜覽第一、二部份之細節敘述後，再行覆卷，較易獲致全盤概念。

㈢第一部份請僅擇一答覆。

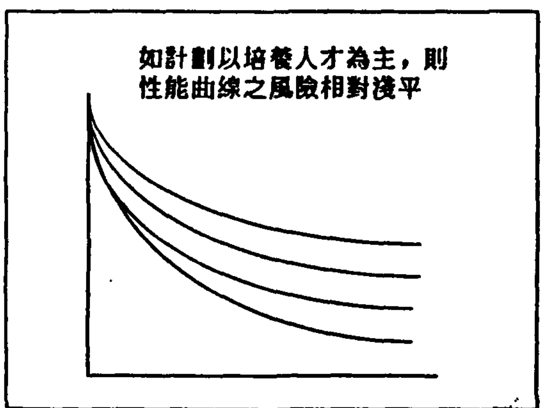
(四)第二部份請針對所列各項可能變因考量後排序，如所列可能變因尚不足以涵蓋者，請逕予敘述並排序之。

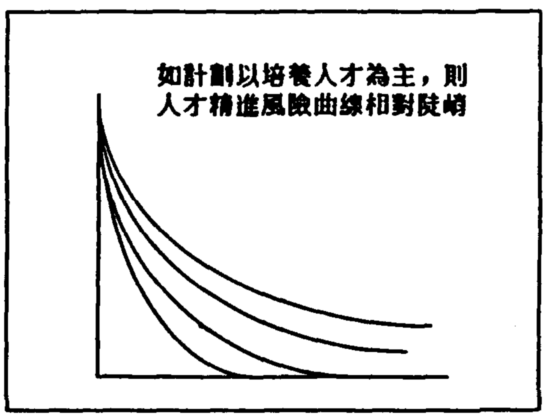
(五)基於風險程度之考量因人而異，為利於思考建議儀可能量化成機率值（ 1% 34% 50% 68% 99%等 ），以下之簡圖及說明或有助益於您量化風險及覆卷之用。

時程 （或成本、性能....）風險圖



例如，計劃時程在現在主、客觀環境因素不變之情況下，有可能50%之機率，時程落後10%，則可能算是低風險，因為X座標與Y座標之交點落於低風險區。唯各曲線之曲度依各人看法而有不同，例如計劃之目標重點如果是培養科技人才，則『性能』、『時程』、『成本』....之風險曲度會相對淺平，而『人才技術精進』則相對陡峭，以凸顯偏離目標之嚴重性，如下二圖：





壹、有關於您的問卷

一、姓名 陳溪豪 （自由填具）
二、單位級職 中校副組長（自由填具）
三、管理計劃之年資（請約至小數點一位） 1.1年
四、您的管理工作係偏重於：

工程　　一般性　　（請擇一）

五、對國防武器系統計劃獲得管理之自我評估（請於以下擇一）

(一) 甚為稱職　（對日常管理工作、決策分析及決定感到輕易無礙、並能充分勝任而愉快）

(二) 稱　職　（對日常計劃管理工作、決策分析及決定，雖有少許困難，唯大多勝任愉快）

(三) 尚　可　（對日常管理工作或感到許多壓力並對決策分析及決定感覺不易完全掌握，然此為多數人之現象）

(四) 待加強　（對日常管理工作及決策分析，與決策決定感覺吃力，有必要作一調整或訓練後必能勝任）

(五) 甚難勝任　（對計劃之日常管理及決策分析與決定感到甚為困難、沮喪，時有離職之想法）

六、在您日常生活中，您是屬於下列何種風險性向？

冒險型　　中立型　　保守型

（例：如您在股票交易中傾向於買投機股多於投資股，則您即是冒險型，如您在購買股票前翻閱各上市公司財務報表、資產負債表等後，才慎而決定，即屬保守型）

七、您是否熟悉在風險管理方面。有一些工具或技巧可利用，諸如分工結構（ Work Breakdown Structure ）成本／時程控制系統（ Cost／Schedule Control System Criteria ）及計劃評核術（ Program Evaluation Review Technique）等等（或其他您知道的工具或方法）。

是　　一些　　否

八、如您對第七項的答案是『是』或『一些』，您是否運用或要求廠商或屬下運用此些工具？

是　　否

陸、計劃『管理』風險之問卷調查

(一)第一部份：

依您的經驗及瞭解，如目前之武器系統獲得之各項主、客觀因素不變（預算支援度、武器系統獲得政策、軍種及中科院執行計劃之能力、信心、人力等等），對任何計劃而言，管理之時程風險為何？

（管理風險之定義：對武器系統獲得之管理難以順遂之程度，以致於影響計劃主體。）

請擇一打鈎：

甚高風險　高風險　普通風險　低風險　甚低風險

(二)第二部份：

就第一部份您的看法（選擇），如您的選擇是屬於甚高、高或普通風險程度，請惠予繼續就下列所列之各項可能肇因擇數項（或者如您認為僅一項，則擇一項），依1.2.3.....之序填於左方括弧欄。

例：（3）1.×××××
　　（2）2.×××××
　　（1）3.×××××

（3）1.需求定義不清或頻於變更，致使管理工作趨於複雜。

（2）2.研發者、使用者、督導者....各方之權責界定模糊，或者與合約商訂約內容不明確，滋生困擾。

（1）3.時程／成本管理及風險管理計劃未列入主計劃內執行，使計劃管理風險增加。

（3）4.組織內部獎勵、罰則不明，工作績效及效率難以激勵。

（1）5.研發者、使用者對計劃共識及相互瞭解不夠，未能充份合作，致使計劃困難度增加。

（1）6.管理能力、技巧及相關知識待加強，以減低管理風險。

（1）7.組織內部陳腐，缺乏效率，領導素養不佳，使管理工作疲於應付。

（　）8.其他（請簡述於後）：

管理者應明瞭專案管理和功能性組織之管理特性不同。
(Project mgt.)　(Fuctional Mgt.)
且應了解武器系統之特性，保持良好之適應能力及彈性，不斷對決策依狀況做科學化，明確之分析而下達，方能降低管理風險。

(三)第三部份：對管理風險之自由意見欄。

貳、性能風險問卷調

㈠第一部份：

依您的經驗及瞭解，如目前武器系統獲得之各項主、客觀因素（預算支援度、武器系統獲得政策、軍種及中科院執行計劃之能力、信心等等）不變，對任何計劃而言，系統性能風險為何？
（性能風險定義：所釐訂之系統操作能力、酬載能力、處理能力等效益性目標有潛在影響因素，而無達成原預定目標之程度。）

請擇一打鉤　：

甚高風險　　高風險　　普通風險　　低風險　　甚低風險

㈡第二部份：

就第一部份您的看法（選擇），如您的選擇是屬於甚高、高或普通程度的風險，請惠予繼續就下列所列之各項可能肇因之輕重影響程度擇數項（或者如您認為僅一項為其肇因，則擇一項），依1,2,3.....之序填於左方括弧欄。（1為主因，2為次因.....）

例：（2）1.××××××
　　（3）2.××××××
　　（1）3.××××××

（1）1.系統之需求文件(Requirements)定義不清楚或不切實際。
（1）2.系統之設計分析工作草率，需求未能妥善納入系統設計中。
（1）3.系統構型管制工作鬆散，研發者及使用者未能掌握構型演進或缺乏構型分析能力。
（2）4.研究發展之測試評估工作完全由研發者執行，或及測試評估主計畫未能適時徹底執行。
（2）5.技術瓶頸不少，且未能利用原型系統在研究發展階段之前找出問題所在。
（2）6.管理及／或技術人力不足，照顧不週。
（2）7.時程壓力太緊，無法有效完成應執行之各階段各階層工作，只好降低性能目標。
（1）8.研發者及使用者雙方或一方對計劃管理不彰、管理能力不足或政策干預太多，無法有效管理。
（2）9.品質管制未詳予列入計劃中實施，或者無法有效獨立作業，以致品質風險無法掌握。
（3）10.其他：（請簡述於後）
系統概念設計時未依威脅增長及科技突破之趨勢，考量系統於研展工程階段（EMD PHASE），適時將新科技納入（Technology Insertion），確保系統服役時仍[illegible]制敵。

㈢第三部份：對性能風險之自由意見欄。
1. USER / DEVELOPER / VENDOR 之 COMMUNICATION 不足。
2. USER PARTICIPATION 因 USER 本身能力 及 DEVELOPER 觀念偏差而不足。
3. 測試管理效率低，致無充足決策參考資料，構型無法有效管制，性能遂無法達到 USER 要求，否則仍需變更之 ECP 補救，風險極高。

註：問卷所列之肇因係參照美國防部頒『Transition From Development To Production』及『Best Practice』兩手冊所列之各項注意因素融合而成。

叁、適應性風險問卷調查

㈠第一部份：

依您的經驗與瞭解，如目前武器系統各項主、客觀因素（預算支援度、武器系統獲得政策、軍種及中科院執行計劃的能力、信心等等）不變，對任何計劃而言，系統適應性之風險為何？
（適應性風險定義：所釐訂之系統適應性能力，諸如，可靠度、維修度、支援度及系統安全等適應性目標有潛在因素影響而無法達成原訂目標之程度）

請擇一打鉤：

甚高風險　　高風險　　普通風險　　低風險　　甚低風險

㈡第二部份：

就第一部份您的看法（選擇），如您的選擇是屬於甚高、高、或普通風險，請惠予繼續就下列所列之各項可能肇因擇數項（或者如您認為僅一項為其肇因，則擇一項），依1.2.3.....之序填於左方括弧欄。

例：（2）1.××××××
（3）2.××××××
（1）3.××××××

（2）1.研發者負計劃之後勤支援分析之責。
（1）2.後勤支援有關參數於性能參數釐訂後方才建立或確立。
（2）3.適應性之諸項參數之需求釐訂不切實際或不清楚。
（3）4.訓練裝備及用具等設計係依初期測試評估人員訓練需求而設計，忽略服役階段操作、維修人員與測評人員之技術與各方面之可能差異。
（3）5.人員技術能力等級及人力需求，係依已服役之裝備系統之經驗推定，缺乏分析結論。
（1）6.系統備份件之籌補於系統發展階段即已執行，未考慮好系統構型之修改變更問題，或系統備份件籌補以零附件料號為基準，支詳查規範。
（3）7.技令文件資料係依研發階段獲得之後勤支援分析結果，未考量生產階段構型。
（1）8.適應性規劃及工作人力不足或經驗及能力不足，無法全盤掌握各階段及各階層工作。
（2）9.時程壓力太緊，無法有效完成各階段各階層工作。
（1）10.研發者或使用者雙方或一方對計劃管理不彰、管理能力不足或政策干預太多無法有效管理。
（　）11.其他（請簡述於後）：

①研發者未詳研究使用者之適應性需求，且不接受使用者依威脅所定之需求基準，執著於科技角度，不願改變。
②研發者不了解何謂適應性？未警覺到適應性對作戰之嚴重影響。
③研發者與使用者互相缺乏溝通技巧。

㈡第二部份：對適應性風險之自由意見欄：

適應性應由使用者依平時及戰時環境及想定來訂定。
(ENVIRONMENT)　(Scenarios)

研發者應協助分析及分配(allocation)，並儘請級科技
(analysis)

肆、計劃之成本風險問卷調查

㈠第一部份：

依您的經驗及瞭解，如目前之武器系統獲得之各項主、客觀因素（預算支援度、武器系統獲得政策、軍種及中科院執行計劃之能力、信心．．．．等等）不變，對任何計劃而言，系統成本風險為何？

（成本風險定義：所計劃之預算目標可能因潛在因素造成總體預算（系統整個壽命週期）及或各階段預算超出之程度。）

請擇一打鈎：

甚高風險　　高風險　　普通風險　　低風險　　甚低風險

㈡第二部份：

就第一部份您的看法（選擇），如您的選擇是屬於甚高、高或普通風險程度，請惠予繼續就下列所列之各項可能肇因擇數項（或者如您認為僅一項為其肇因，則擇一項），依1.2.3.．．．．之序填於左方括弧欄。

例：（4）1.×××××

（3）2.×××××

（1）3.×××××

（2）1.需求定義不清楚或需求頻於變更，以至於可能導致甚多工程修改或重新設計。

（2）2.後勤需求規劃不週或執行不確實，影響系統服役之維持成本。

（1）3.技術風險太高或運用未臻成熟科技。

（1）4.測試評估未能確實執行（人為或時程影響），以致系統不確定性增高。

（1）5.單一商源，缺乏成本管制之概念或壓力。

（2）6.計劃時程太緊，無法有效完成應執行工作，以致計劃不確定性增高。

（3）7.成本管制漫無效率或缺乏成本管制追蹤之整體計劃。

（2）8.其他（請簡述於後）：

工作分析不夠詳細，太籠統，致不易評估（measurement）宜以80小時為一package，較易管制掌握。

㈢第三部份：對成本風險之自由意見欄。

Work Breakdown Structure 不確實。

伍、時程風險問卷調查

(一)第一部份：

依您的經驗及瞭解，如目前之武器系統獲得之各項主、客觀因素（預算支援度、武器系統獲得政策、軍種及中科院執行計劃之能力、信心....等等 ）不變，對任何計劃而言，系統之時程風險為何？
（ 時程風險之定義：系統無法按既定時程依所期望之系統能力完成交運之程度。 ）

請擇一打鈎：

甚高風險　　高風險　　普通風險　　低風險　　甚低風險

(二)第二部份：

就第一部份您的看法（ 選擇 ），如您的選擇是屬於甚高、高或普通風險程度，請惠予繼續就下列所列之各項可能肇因擇數項（ 或者如您認為僅一項為其肇因，則擇一項 ），依1.2.3.....之序填於左方括弧欄。

例：（3） 1.×××××
（1） 2.×××××
（2） 3.×××××

（ 1 ） 1.需求定義不清或需求頻於變更，以致於增加甚多工程修改及重新設計之工作。
（ 1 ） 2.構型管制鬆散，以致於時程無法加以管制。
（ 1 ） 3.次合約商之管理不彰，無法掌握計劃進度。
（ 1 ） 4.計劃未能運用分工結構系統（ Work Breakdown Structure ）策訂工作時程並加以管制各分項工作。
（ 2 ） 5.引進未臻成熟科技或技術障礙有待克服。
（ 2 ） 6.整體之測試工作未能按計劃執行或未詳予規劃（ 含品管 ），以致於可能會造成多項重覆工作，以解決不滿意件。
（ 3 ） 7.本身時程壓力太，以致於未能完成應執行工作，反而造成時程落後。
（ 2 ） 8.各階段工作未能整體規劃，缺乏統一性，致使下階段工作可能因變數多而無法規劃、掌握時程，例如：設計未考量生產製造問題，研發未考量修改及測試問題等。
（ 1 ） 9.其他（ 請簡述於後 ）：

時程之規劃未運用適當工具 (tools) 如：
· PERT (Project Evaluation Review Technique).
· CPM (Critical Path Method)
做精確之分析、及修正 (update) 以降低時程風險。

(三)第三部份：時程風險自由意見欄：

大環境 (external Environment) 之變化分析及預判.
小環境 (internal ,,) ,,
均對重大時程風險因素可提供一參考。

Appendix C: Summarized Data for Performance Risk Magnitudes Rated by Respondents

CASE	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW
1	0.0000	1.0000	0.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000	0.0000	0.0000
3	0.0000	1.0000	0.0000	0.0000	0.0000
4	0.0000	1.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	1.0000	0.0000	0.0000
6	0.0000	1.0000	0.0000	0.0000	0.0000
7	1.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	1.0000	0.0000	0.0000
9	0.0000	0.0000	1.0000	0.0000	0.0000
10	0.0000	0.0000	1.0000	0.0000	0.0000
11	1.0000	0.0000	0.0000	0.0000	0.0000
12	1.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	1.0000	0.0000	0.0000	0.0000
14	1.0000	0.0000	0.0000	0.0000	0.0000
15	0.0000	1.0000	0.0000	0.0000	0.0000
16	0.0000	1.0000	0.0000	0.0000	0.0000
17	0.0000	1.0000	0.0000	0.0000	0.0000
18	1.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	1.0000	0.0000	0.0000	0.0000
20	0.0000	1.0000	0.0000	0.0000	0.0000
21	0.0000	1.0000	0.0000	0.0000	0.0000
22	0.0000	1.0000	0.0000	0.0000	0.0000
23	0.0000	1.0000	0.0000	0.0000	0.0000
24	0.0000	0.0000	1.0000	0.0000	0.0000
25	0.0000	1.0000	0.0000	0.0000	0.0000
26	0.0000	0.0000	1.0000	0.0000	0.0000
27	0.0000	0.0000	0.0000	1.0000	0.0000
28	0.0000	0.0000	1.0000	0.0000	0.0000
29	0.0000	1.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	0.0000	1.0000	0.0000
31	0.0000	0.0000	1.0000	0.0000	0.0000
32	0.0000	1.0000	0.0000	0.0000	0.0000
33	0.0000	1.0000	0.0000	0.0000	0.0000
34	0.0000	0.0000	1.0000	0.0000	0.0000
35	0.0000	1.0000	0.0000	0.0000	0.0000
36	0.0000	0.0000	0.0000	1.0000	0.0000
37	0.0000	0.0000	1.0000	0.0000	0.0000
38	0.0000	0.0000	1.0000	0.0000	0.0000
39	0.0000	1.0000	0.0000	0.0000	0.0000
40	0.0000	0.0000	1.0000	0.0000	0.0000
41	0.0000	0.0000	0.0000	1.0000	0.0000
42	0.0000	0.0000	0.0000	1.0000	0.0000
43	0.0000	0.0000	1.0000	0.0000	0.0000

Summarized Data for Performance Risk Magnitudes Rated by Respondents (Cont)

44	0.0000	0.0000	1.0000	0.0000	0.0000
45	0.0000	1.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	0.0000	1.0000	0.0000
47	0.0000	0.0000	1.0000	0.0000	0.0000
48	0.0000	0.0000	1.0000	0.0000	0.0000
49	0.0000	0.0000	1.0000	0.0000	0.0000
50	0.0000	0.0000	1.0000	0.0000	0.0000
51	0.0000	0.0000	0.0000	1.0000	0.0000
52	0.0000	0.0000	1.0000	0.0000	0.0000
53	0.0000	1.0000	0.0000	0.0000	0.0000
54	0.0000	1.0000	0.0000	0.0000	0.0000

Appendix D: Ranked Data for Performance Risk Drivers

CASE	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN
1	4.0000	2.0000	3.0000	0.0000	0.0000	0.0000	1.0000
2	0.0000	1.0000	0.0000	2.0000	3.0000	0.0000	4.0000
3	2.0000	3.0000	5.0000	6.0000	1.0000	0.0000	4.0000
4	0.0000	3.0000	4.0000	2.0000	9.0000	8.0000	1.0000
5	0.0000	0.0000	0.0000	2.0000	3.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	4.0000	3.0000	0.0000	2.0000
7	1.0000	5.0000	6.0000	7.0000	2.0000	4.0000	9.0000
8	5.0000	6.0000	4.0000	7.0000	3.0000	0.0000	1.0000
9	5.0000	8.0000	9.0000	3.0000	1.0000	7.0000	2.0000
10	3.0000	8.0000	1.0000	4.0000	6.0000	2.0000	7.0000
11	2.0000	1.0000	2.0000	3.0000	4.0000	1.0000	6.0000
12	7.0000	8.0000	5.0000	6.0000	1.0000	3.0000	2.0000
13	3.0000	4.0000	5.0000	6.0000	9.0000	1.0000	2.0000
14	0.0000	0.0000	3.0000	0.0000	2.0000	1.0000	0.0000
15	1.0000	2.0000	3.0000	3.0000	2.0000	1.0000	3.0000
16	1.0000	3.0000	1.0000	2.0000	1.0000	1.0000	2.0000
17	2.0000	0.0000	4.0000	0.0000	0.0000	0.0000	1.0000
18	3.0000	6.0000	7.0000	5.0000	8.0000	1.0000	4.0000
19	1.0000	2.0000	0.0000	2.0000	0.0000	2.0000	0.0000
20	3.0000	0.0000	0.0000	0.0000	0.0000	4.0000	2.0000
21	1.0000	2.0000	6.0000	3.0000	4.0000	5.0000	6.0000
22	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	2.0000
23	2.0000	1.0000	3.0000	4.0000	5.0000	8.0000	6.0000
24	7.0000	8.0000	5.0000	6.0000	1.0000	3.0000	2.0000
25	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	1.0000
26	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	2.0000
27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.0000
28	5.0000	0.0000	0.0000	4.0000	3.0000	0.0000	2.0000
29	2.0000	8.0000	9.0000	7.0000	1.0000	6.0000	3.0000
30	4.0000	0.0000	0.0000	0.0000	1.0000	2.0000	0.0000
31	3.0000	0.0000	0.0000	5.0000	0.0000	4.0000	1.0000
32	1.0000	0.0000	0.0000	0.0000	3.0000	0.0000	2.0000
33	0.0000	0.0000	0.0000	0.0000	1.0000	3.0000	2.0000
34	1.0000	2.0000	2.0000	2.0000	1.0000	2.0000	2.0000
35	0.0000	0.0000	0.0000	0.0000	3.0000	2.0000	1.0000
36	0.0000	0.0000	0.0000	2.0000	0.0000	0.0000	1.0000
37	2.0000	2.0000	3.0000	3.0000	2.0000	3.0000	1.0000
38	2.0000	2.0000	3.0000	2.0000	2.0000	1.0000	1.0000
39	0.0000	0.0000	0.0000	3.0000	1.0000	2.0000	0.0000
40	1.0000	0.0000	0.0000	0.0000	3.0000	4.0000	5.0000
41	1.0000	5.0000	4.0000	8.0000	3.0000	9.0000	6.0000
42	0.0000	0.0000	0.0000	3.0000	1.0000	2.0000	0.0000
43	1.0000	0.0000	0.0000	0.0000	3.0000	4.0000	5.0000
44	1.0000	2.0000	3.0000	1.0000	2.0000	1.0000	1.0000

Ranked Data for Performance Risk Drivers (Cont)

45	6.0000	7.0000	5.0000	9.0000	4.0000	3.0000	2.0000
46	1.0000	0.0000	0.0000	0.0000	0.0000	2.0000	3.0000
47	0.0000	2.0000	3.0000	0.0000	1.0000	5.0000	4.0000

Ranked Data for Performance Risk Drivers (Cont)

CASE	EIGHT	NINE	TEN
1	5.0000	6.0000	0.0000
2	0.0000	0.0000	0.0000
3	7.0000	8.0000	0.0000
4	6.0000	7.0000	0.0000
5	1.0000	0.0000	0.0000
6	1.0000	0.0000	0.0000
7	3.0000	8.0000	1.0000
8	2.0000	0.0000	0.0000
9	4.0000	6.0000	0.0000
10	5.0000	9.0000	0.0000
11	1.0000	5.0000	0.0000
12	4.0000	9.0000	0.0000
13	8.0000	7.0000	0.0000
14	0.0000	0.0000	0.0000
15	2.0000	1.0000	0.0000
16	1.0000	1.0000	0.0000
17	3.0000	0.0000	5.0000
18	2.0000	9.0000	0.0000
19	3.0000	0.0000	0.0000
20	1.0000	0.0000	0.0000
21	8.0000	7.0000	0.0000
22	1.0000	2.0000	3.0000
23	7.0000	9.0000	0.0000
24	4.0000	9.0000	0.0000
25	3.0000	0.0000	0.0000
26	0.0000	0.0000	0.0000
27	0.0000	0.0000	1.0000
28	1.0000	0.0000	0.0000
29	4.0000	5.0000	0.0000
30	3.0000	0.0000	0.0000
31	2.0000	0.0000	0.0000
32	0.0000	0.0000	0.0000
33	0.0000	0.0000	0.0000
34	2.0000	2.0000	0.0000
35	1.0000	0.0000	0.0000
36	3.0000	0.0000	0.0000
37	3.0000	1.0000	0.0000
38	2.0000	3.0000	0.0000
39	0.0000	0.0000	0.0000
40	2.0000	0.0000	0.0000
41	2.0000	7.0000	0.0000
42	0.0000	0.0000	0.0000
43	2.0000	0.0000	0.0000
44	1.0000	2.0000	0.0000
45	1.0000	8.0000	0.0000
46	0.0000	0.0000	0.0000
47	0.0000	0.0000	0.0000

Appendix E: Ranked Data for Performance Risk Drivers after Ties

CASE	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN
1	4.0000	2.0000	3.0000	8.5000	8.5000	8.5000	1.0000
2	7.5000	1.0000	7.5000	2.0000	3.0000	7.5000	4.0000
3	2.0000	3.0000	5.0000	6.0000	1.0000	9.5000	4.0000
4	5.0000	3.0000	4.0000	2.0000	9.0000	8.0000	1.0000
5	7.0000	7.0000	7.0000	2.0000	3.0000	7.0000	7.0000
6	7.5000	7.5000	7.5000	4.0000	3.0000	7.5000	2.0000
7	1.0000	6.0000	7.0000	8.0000	3.0000	5.0000	10.000
8	5.0000	6.0000	4.0000	7.0000	3.0000	9.0000	1.0000
9	5.0000	8.0000	9.0000	3.0000	1.0000	7.0000	2.0000
10	3.0000	8.0000	1.0000	4.0000	6.0000	2.0000	7.0000
11	4.5000	2.0000	4.5000	6.0000	7.0000	2.0000	9.0000
12	7.0000	8.0000	5.0000	6.0000	1.0000	3.0000	2.0000
13	3.0000	4.0000	5.0000	6.0000	9.0000	1.0000	2.0000
14	7.0000	7.0000	3.0000	7.0000	2.0000	1.0000	7.0000
15	2.0000	5.0000	8.0000	8.0000	5.0000	2.0000	8.0000
16	3.5000	9.0000	3.5000	7.5000	3.5000	3.5000	7.5000
17	2.0000	8.0000	4.0000	8.0000	8.0000	8.0000	1.0000
18	3.0000	6.0000	7.0000	5.0000	8.0000	1.0000	4.0000
19	1.0000	3.0000	8.0000	3.0000	8.0000	3.0000	8.0000
20	3.0000	7.5000	7.5000	7.5000	7.5000	4.0000	2.0000
21	1.0000	2.0000	6.5000	3.0000	4.0000	5.0000	6.5000
22	2.5000	2.5000	2.5000	7.0000	7.0000	7.0000	7.0000
23	2.0000	1.0000	3.0000	4.0000	5.0000	8.0000	6.0000
24	7.0000	8.0000	5.0000	6.0000	1.0000	3.0000	2.0000
25	7.0000	7.0000	7.0000	7.0000	2.0000	7.0000	1.0000
26	6.5000	1.0000	6.5000	6.5000	6.5000	6.5000	2.0000
27	6.5000	6.5000	6.5000	6.5000	6.5000	6.5000	2.0000
28	5.0000	8.0000	8.0000	4.0000	3.0000	8.0000	2.0000
29	2.0000	8.0000	9.0000	7.0000	1.0000	6.0000	3.0000
30	4.0000	7.5000	7.5000	7.5000	1.0000	2.0000	7.5000
31	3.0000	8.0000	8.0000	5.0000	8.0000	4.0000	1.0000
32	1.0000	7.0000	7.0000	7.0000	3.0000	7.0000	2.0000
33	7.0000	7.0000	7.0000	7.0000	1.0000	3.0000	2.0000
34	1.5000	5.0000	5.0000	5.0000	1.5000	5.0000	5.0000
35	7.5000	7.5000	7.5000	7.5000	4.0000	3.0000	1.5000
36	7.0000	7.0000	7.0000	2.0000	7.0000	7.0000	1.0000
37	4.0000	4.0000	7.5000	7.5000	4.0000	7.5000	1.5000
38	5.0000	5.0000	8.5000	5.0000	5.0000	1.5000	1.5000
39	7.0000	7.0000	7.0000	3.0000	1.0000	2.0000	7.0000
40	1.0000	8.0000	8.0000	8.0000	3.0000	4.0000	5.0000
41	1.0000	5.0000	4.0000	8.0000	3.0000	9.0000	6.0000
42	7.0000	7.0000	7.0000	3.0000	1.0000	2.0000	7.0000
43	1.0000	8.0000	8.0000	8.0000	3.0000	4.0000	5.0000
44	3.0000	7.0000	9.0000	3.0000	7.0000	3.0000	3.0000

Ranked Data for Performance Risk Drivers after Ties (Cont)

45	6.0000	7.0000	5.0000	9.0000	4.0000	3.0000	2.0000
46	1.0000	7.0000	7.0000	7.0000	7.0000	2.0000	3.0000
47	8.0000	2.0000	3.0000	8.0000	1.0000	5.0000	4.0000

Ranked Data for Performance Risk Drivers after Ties (Cont)

CASE	EIGHT	NINE	TEN
1	5.0000	6.0000	8.5000
2	7.5000	7.5000	7.5000
3	7.0000	8.0000	9.5000
4	6.0000	7.0000	10.000
5	1.0000	7.0000	7.0000
6	1.0000	7.5000	7.5000
7	4.0000	9.0000	1.0000
8	2.0000	9.0000	9.0000
9	4.0000	6.0000	10.000
10	5.0000	9.0000	10.000
11	2.0000	8.0000	10.000
12	4.0000	9.0000	10.000
13	8.0000	7.0000	10.000
14	7.0000	7.0000	7.0000
15	5.0000	2.0000	10.000
16	3.5000	3.5000	10.000
17	3.0000	8.0000	5.0000
18	2.0000	9.0000	10.000
19	5.0000	8.0000	8.0000
20	1.0000	7.5000	7.5000
21	9.0000	8.0000	10.000
22	2.5000	7.0000	10.000
23	7.0000	9.0000	10.000
24	4.0000	9.0000	10.000
25	3.0000	7.0000	7.0000
26	6.5000	6.5000	6.5000
27	6.5000	6.5000	1.0000
28	1.0000	8.0000	8.0000
29	4.0000	5.0000	10.000
30	3.0000	7.5000	7.5000
31	2.0000	8.0000	8.0000
32	7.0000	7.0000	7.0000
33	7.0000	7.0000	7.0000
34	5.0000	5.0000	10.000
35	1.5000	7.5000	7.5000
36	3.0000	7.0000	7.0000
37	7.5000	1.5000	10.000
38	5.0000	8.5000	10.000
39	7.0000	7.0000	7.0000
40	2.0000	8.0000	8.0000
41	2.0000	7.0000	10.000
42	7.0000	7.0000	7.0000
43	2.0000	8.0000	8.0000
44	3.0000	7.0000	10.000
45	1.0000	8.0000	10.000
46	7.0000	7.0000	7.0000
47	8.0000	8.0000	8.0000

Appendix F: Summarized Data for Supportability Risk Magnitudes Rated by Respondents

CASE	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW
1	0.0000	1.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	1.0000	0.0000	0.0000
3	0.0000	1.0000	0.0000	0.0000	0.0000
4	0.0000	1.0000	0.0000	0.0000	0.0000
5	0.0000	1.0000	0.0000	0.0000	0.0000
6	0.0000	1.0000	0.0000	0.0000	0.0000
7	1.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	1.0000	0.0000	0.0000	0.0000
9	0.0000	1.0000	0.0000	0.0000	0.0000
10	1.0000	0.0000	0.0000	0.0000	0.0000
11	1.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	1.0000	0.0000	0.0000
13	0.0000	1.0000	0.0000	0.0000	0.0000
14	0.0000	1.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	1.0000	0.0000	0.0000
16	0.0000	1.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	1.0000	0.0000	0.0000
18	1.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	1.0000	0.0000	0.0000	0.0000
20	0.0000	1.0000	0.0000	0.0000	0.0000
21	0.0000	1.0000	0.0000	0.0000	0.0000
22	0.0000	1.0000	0.0000	0.0000	0.0000
23	0.0000	1.0000	0.0000	0.0000	0.0000
24	0.0000	1.0000	0.0000	0.0000	0.0000
25	0.0000	1.0000	0.0000	0.0000	0.0000
26	0.0000	0.0000	0.0000	1.0000	0.0000
27	0.0000	0.0000	0.0000	1.0000	0.0000
28	0.0000	1.0000	0.0000	0.0000	0.0000
29	0.0000	0.0000	1.0000	0.0000	0.0000
30	0.0000	1.0000	0.0000	0.0000	0.0000
31	0.0000	0.0000	1.0000	0.0000	0.0000
32	0.0000	0.0000	1.0000	0.0000	0.0000
33	0.0000	0.0000	1.0000	0.0000	0.0000
34	0.0000	0.0000	1.0000	0.0000	0.0000
35	0.0000	0.0000	1.0000	0.0000	0.0000
36	0.0000	1.0000	0.0000	0.0000	0.0000
37	0.0000	0.0000	0.0000	1.0000	0.0000
38	0.0000	1.0000	0.0000	0.0000	0.0000
39	0.0000	0.0000	1.0000	0.0000	0.0000
40	0.0000	0.0000	0.0000	1.0000	0.0000
41	0.0000	0.0000	0.0000	1.0000	0.0000
42	0.0000	0.0000	0.0000	1.0000	0.0000
43	0.0000	0.0000	1.0000	0.0000	0.0000

Summarized Data for Supportability Risk Magnitudes Rated by Respondents (Cont)

44	0.0000	1.0000	0.0000	0.0000	0.0000
45	0.0000	1.0000	0.0000	0.0000	0.0000
46	0.0000	1.0000	0.0000	0.0000	0.0000
47	0.0000	0.0000	0.0000	1.0000	0.0000
48	0.0000	0.0000	1.0000	0.0000	0.0000
49	0.0000	0.0000	1.0000	0.0000	0.0000
50	0.0000	1.0000	0.0000	0.0000	0.0000
51	0.0000	0.0000	1.0000	0.0000	0.0000
52	0.0000	0.0000	1.0000	0.0000	0.0000
53	0.0000	0.0000	1.0000	0.0000	0.0000

Appendix G: Ranked Data for Supportability Risk Drivers

Case	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
1	5		1		2		6	4	3	7	
2			1	2		4	3				
3		7	6	5	2	4	3	1	8		
4	10	8	9	6	7	1	4	5	2	3	
5						1		2			
6			2			4		1	5	3	
7	4	6	5	10	7	8	9	2	11	3	1
8		2			5	1	3		4		
9						3			1	4	2
10	10	1	2	8	9	3	5	4	6	7	
11						2		1		1	
12		5	1	6	2			7	3	4	
13	10	6	5	7	8	4	9	3	1	2	
14	4			2	3			1	2	5	
15	2	2	2	1	2	1	1	2	3	3	
16	1	2	1	1	2	1	1	1	2	2	
17	5	3	4					1	2		
18	4	3	5	7	8	9	10	2	6	1	
19	1				2	2		1		3	
20						1	2				
21	1	2	5	6	5	7	8	4	4	3	
22	2	1	2	3	3	1	3	1	2	1	
23		5	1	6	2	9	8	7	3	4	
24	1	3	2		4			5			
25		6		5		1		2	4	3	
26	1	2	2								
27				2	3	1		4	5		
28		3	4		1				2		
29				4		5		3	2		1
30	10	9	1	8	7	3	4	6	2	5	
31		3						4	2	1	
32	7	5	6	1	2	10	3	4	8	9	
33		3	4		1	5		2			
34		3			4	5	6	1	2		
35			2					1			
36				3				1	2		
37				3				1	2	3	
38					3	1			2		
39	3	1	2	2	2	3	2	1	1	1	
40	1	2	3	1	2	2	2	2	3	2	
41				3	2	1					
42		3	1					4	5	2	
43	10	6	5	1	7	8	9	4	2	3	

Ranked Data for Supportability Risk Drivers (Cont)

44			3	2	1				
45	3	1					4	5	2
46		1	4	2			3	5	

Appendix H: Ranked Data for Supportability Risk Drivers after Ties

Case	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
1	5	9.5	1	9.5	2	9.5	6	4	3	7	9.5
2	8	8	1	2	8	4	3	8	8	8	8
3	10	7	6	5	2	4	3	1	8	10	10
4	10	8	9	6	7	1	4	5	2	3	11
5	7	7	7	7	7	1	7	2	7	7	7
6	8.5	8.5	2	8.5	8.5	4	8.5	1	5	3	8.5
7	4	6	5	10	7	8	9	2	11	3	1
8	8.5	2	8.5	8.5	5	1	3	8.5	4	8.5	8.5
9	8	8	8	8	8	3	8	8	1	4	2
10	10	1	2	8	9	3	5	4	6	7	11
11	7.5	7.5	7.5	7.5	7.5	3	7.5	1.5	7.5	1.5	7.5
12	9.5	5	1	6	2	9.5	9.5	7	3	4	9.5
13	10	6	5	7	8	4	9	3	1	2	11
14	5	8.5	8.5	2.5	4	8.5	8.5	1	2.5	5	8.5
15	6	6	6	2	6	2	2	6	10	10	10
16	3.5	8.5	3.5	3.5	8.5	3.5	3.5	3.5	8.5	8.5	11
17	5	3	4	8.5	8.5	8.5	8.5	1	2	8.5	8.5
18	4	3	5	7	8	9	10	2	6	1	11
19	1.5	8.5	8.5	8.5	3.5	3.5	8.5	1.5	8.5	5	8.5
20	7	7	7	7	7	1	2	7	7	7	7
21	1	2	6	8	7	9	10	4.5	4.5	3	11
22	6	2.5	6	9	9	2.5	9	2.5	6	2.5	11
23	10.5	5	1	6	2	9	8	7	3	4	10.5
24	1	3	2	8.5	4	8.5	8.5	5	8.5	8.5	8.5
25	8.5	6	8.5	5	8.5	1	8.5	2	4	3	8.5
26	1	2.5	2.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
27	8.5	8.5	8.5	2	3	1	8.5	4	5	8.5	8.5
28	8	3	4	8	1	8	8	8	2	8	8
29	8.5	8.5	8.5	4	8.5	5	8.5	3	2	8.5	1
30	10	9	1	8	7	3	4	6	2	5	11
31	8	3	8	8	8	8	8	4	2	1	8
32	7	5	6	1	2	10	3	4	8	9	11
33	8.5	3	4	8.5	1	5	8.5	2	8.5	8.5	8.5
34	9	3	9	9	4	5	6	1	2	9	9
35	7	7	2	7	7	7	7	1	7	7	7
36	7.5	7.5	7.5	3	7.5	7.5	7.5	1	2	7.5	7.5
37	8	8	8	3.5	8	8	8	1	2	3.5	8
38	7.5	7.5	7.5	7.5	3	1	7.5	7.5	2	7.5	7.5
39	9.5	2.5	6.5	6.5	6.5	9.5	6.5	2.5	2.5	2.5	11
40	1.5	5.5	9.5	1.5	5.5	5.5	5.5	5.5	9.5	5.5	11
41	7.5	7.5	7.5	3	2	1	7.5	7.5	7.5	7.5	7.5
42	8.5	3	1	8.5	8.5	8.5	8.5	4	5	2	8.5
43	10	6	5	1	7	8	9	4	2	3	11
44	7.5	7.5	7.5	3	2	1	7.5	7.5	7.5	7.5	7.5
45	8.5	3	1	8.5	8.5	8.5	8.5	4	5	2	8.5

Ranked Data for Supportability Risk Drivers after Ties (Cont)

46	8.5	8.5	1	4	2	8.5	8.5	3	5	8.5	8.5

Appendix I: Summarized Data for Life-Cycle Cost Risk Magnitudes Rated by Respondents

CASE	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW
1	1.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000	0.0000	0.0000
3	0.0000	1.0000	0.0000	0.0000	0.0000
4	0.0000	1.0000	0.0000	0.0000	0.0000
5	0.0000	1.0000	0.0000	0.0000	0.0000
6	0.0000	1.0000	0.0000	0.0000	0.0000
7	0.0000	1.0000	0.0000	0.0000	0.0000
8	0.0000	1.0000	0.0000	0.0000	0.0000
9	0.0000	1.0000	0.0000	0.0000	0.0000
10	0.0000	1.0000	0.0000	0.0000	0.0000
11	1.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	1.0000	0.0000	0.0000
13	1.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	1.0000	0.0000	0.0000	0.0000
15	0.0000	1.0000	0.0000	0.0000	0.0000
16	0.0000	1.0000	0.0000	0.0000	0.0000
17	0.0000	1.0000	0.0000	0.0000	0.0000
18	1.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	1.0000	0.0000	0.0000	0.0000
20	0.0000	1.0000	0.0000	0.0000	0.0000
21	0.0000	1.0000	0.0000	0.0000	0.0000
22	1.0000	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0000	1.0000	0.0000	0.0000
24	0.0000	1.0000	0.0000	0.0000	0.0000
25	0.0000	0.0000	1.0000	0.0000	0.0000
26	0.0000	0.0000	1.0000	0.0000	0.0000
27	0.0000	0.0000	0.0000	1.0000	0.0000
28	0.0000	0.0000	0.0000	1.0000	0.0000
29	0.0000	1.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	1.0000	0.0000	0.0000
31	0.0000	1.0000	0.0000	0.0000	0.0000
32	0.0000	0.0000	1.0000	0.0000	0.0000
33	0.0000	1.0000	0.0000	0.0000	0.0000
34	0.0000	0.0000	1.0000	0.0000	0.0000
35	0.0000	0.0000	1.0000	0.0000	0.0000
36	0.0000	1.0000	0.0000	0.0000	0.0000
37	0.0000	1.0000	0.0000	0.0000	0.0000
38	0.0000	0.0000	0.0000	1.0000	0.0000
39	0.0000	1.0000	0.0000	0.0000	0.0000
40	0.0000	0.0000	1.0000	0.0000	0.0000
41	0.0000	0.0000	1.0000	0.0000	0.0000
42	0.0000	0.0000	0.0000	1.0000	0.0000
43	0.0000	0.0000	1.0000	0.0000	0.0000

Summarized Data for Life-Cycle Cost Risk Magnitudes Rated by Respondents (Cont)

44	0.0000	0.0000	1.0000	0.0000	0.0000
45	0.0000	1.0000	0.0000	0.0000	0.0000
46	0.0000	1.0000	0.0000	0.0000	0.0000
47	0.0000	1.0000	0.0000	0.0000	0.0000
48	0.0000	0.0000	1.0000	0.0000	0.0000
49	0.0000	0.0000	1.0000	0.0000	0.0000
50	1.0000	0.0000	0.0000	0.0000	0.0000
51	0.0000	1.0000	0.0000	0.0000	0.0000
52	0.0000	0.0000	1.0000	0.0000	0.0000
53	1.0000	0.0000	0.0000	0.0000	0.0000
54	0.0000	1.0000	0.0000	0.0000	0.0000

Appendix J: Ranked Data for Life-Cycle Cost Risk Drivers

Case	One	Two	Three	Four	Five	Six	Seven	Eight
1	1	3	5	4	6		2	
2	1	4	3	2				
3	3		1	2	4			
4	5	6	7	4	1	3	2	
5			3	4	2		1	
6	5		1	4	2	3		
7	6	5	1	3	2	7	4	
8	4			3	1	2		
9			2	4	1	5	3	
10	1	2	4	6	7	5	3	
11	2	1	2	3			1	
12	5	6	1	7	2	3	4	
13	1	6	2	5	3	4	7	
14		2	1		3			
15	2	2	2	3	3	3	1	
16	1	1	2	2	1	2	1	
17	3				1	2	4	
18	3	4	6	7	5	2	1	
19	2				1	1	2	
20		2	1				3	
21	3	2	1	4	3	4	5	
22	2	2	1	1	1	2	3	2
23	5	6	1	7	2	3	4	
24	1	2		3	4			
25	1	4			2		3	
26	1	3				2		
27	1	1	2	2	1	1	3	
28	1				2	3		
29	5	4	1	6	3	2	7	
30	3	5	2	4		1	6	
31	2	1	5	7	4	3	6	
32	1				3	2		
33	1	4	2	6	5	3	7	
34	2		3		1			
35	4	3		2	5	1		
36					2		1	
37	1	3				2		
38	1	3	3	1	3	2	3	
39	2	1						
40	1	3			1		3	
41	3				2		1	
42	1	1	2	2	1	2	2	
43	2	2	2	2	1	3	1	
44	1				3	2		

Ranked Data for Life-Cycle Cost Risk Drivers (Cont)

45	1			2			3
46	1	6				2	
47	1	4	2	3	5	7	6
48	1		2				3
49	1	3				2	
50	2	1					

Appendix K: Ranked Data for Life-Cycle Cost Risk Drivers after Ties

Case	One	Two	Three	Four	Five	Six	Seven	Eight
1	1	3	5	4	6	7	2	8
2	1	4	3	2	6.5	6.5	6.5	6.5
3	3	6.5	1	2	4	6.5	6.5	6.5
4	5	6	7	4	1	3	2	8
5	6.5	6.5	3	4	2	6.5	1	6.5
6	5	7	1	4	2	3	7	7
7	6	5	1	3	2	7	4	8
8	4	6.5	6.5	3	1	2	6.5	6.5
9	7	7	2	4	1	5	3	7
10	1	2	4	6	7	5	3	8
11	3.5	1.5	3.5	5	7	7	1.5	7
12	5	6	1	7	2	3	4	8
13	1	6	2	5	3	4	7	8
14	6	2	1	6	3	6	6	6
15	3	3	3	6	6	6	1	8
16	2.5	2.5	6	6	2.5	6	2.5	8
17	3	6.5	6.5	6.5	1	2	4	6.5
18	3	4	6	7	5	2	1	8
19	3.5	6.5	6.5	6.5	1.5	1.5	3.5	6.5
20	6	2	1	6	6	6	3	6
21	3.5	2	1	5.5	3.5	5.5	7	8
22	5.5	5.5	2	2	2	5.5	8	5.5
23	5	6	1	7	2	3	4	8
24	1	2	6.5	3	4	6.5	6.5	6.5
25	1	4	6.5	6.5	2	6.5	3	6.5
26	1	3	6	6	6	2	6	6
27	2.5	2.5	5.5	5.5	2.5	2.5	7	8
28	1	6	6	6	2	3	6	6
29	5	4	1	6	3	2	7	8
30	3	5	2	4	7.5	1	6	7.5
31	2	1	5	7	4	3	6	8
32	1	6	6	6	3	2	6	6
33	1	4	2	6	5	3	7	8
34	2	6	3	6	1	6	6	6
35	4	3	7	2	5	1	7	7
36	5.5	5.5	5.5	5.5	2	5.5	1	5.5
37	1	3	6	6	6	2	6	6
38	1.5	5.5	5.5	1.5	5.5	3	5.5	8
39	2	1	5.5	5.5	5.5	5.5	5.5	5.5
40	1.5	3.5	6.5	6.5	1.5	6.5	3.5	6.5
41	3	6	6	6	2	6	1	6
42	2	2	5.5	5.5	2	5.5	5.5	8
43	4.5	4.5	4.5	4.5	1.5	7	1.5	8
44	1	6	6	6	3	2	6	6

Ranked Data for Life-Cycle Cost Risk Drivers after Ties (Cont)

45	1	6	6	2	6	6	3	6
46	1	3	6	6	6	2	6	6
47	1	4	2	3	5	7	6	8
48	1	6	6	2	6	6	3	6
49	1	3	6	6	6	2	6	6
50	2	1	5.5	5.5	5.5	5.5	5.5	5.5

Appendix L: Summarized Data for Schedule Risk Magnitudes Rated by Respondents

CASE	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW
1	1.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000	0.0000	0.0000
3	0.0000	1.0000	0.0000	0.0000	0.0000
4	0.0000	1.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	1.0000	0.0000	0.0000
6	0.0000	1.0000	0.0000	0.0000	0.0000
7	0.0000	1.0000	0.0000	0.0000	0.0000
8	0.0000	1.0000	0.0000	0.0000	0.0000
9	0.0000	1.0000	0.0000	0.0000	0.0000
10	0.0000	1.0000	0.0000	0.0000	0.0000
11	1.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	1.0000	0.0000	0.0000	0.0000
13	1.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	1.0000	0.0000	0.0000	0.0000
15	0.0000	1.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	1.0000	0.0000	0.0000
17	0.0000	1.0000	0.0000	0.0000	0.0000
18	1.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	1.0000	0.0000	0.0000	0.0000
20	0.0000	1.0000	0.0000	0.0000	0.0000
21	0.0000	1.0000	0.0000	0.0000	0.0000
22	0.0000	1.0000	0.0000	0.0000	0.0000
23	0.0000	1.0000	0.0000	0.0000	0.0000
24	0.0000	0.0000	1.0000	0.0000	0.0000
25	0.0000	1.0000	0.0000	0.0000	0.0000
26	0.0000	1.0000	0.0000	0.0000	0.0000
27	0.0000	0.0000	1.0000	0.0000	0.0000
28	0.0000	0.0000	0.0000	1.0000	0.0000
29	0.0000	1.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	1.0000	0.0000	0.0000
31	0.0000	1.0000	0.0000	0.0000	0.0000
32	0.0000	0.0000	1.0000	0.0000	0.0000
33	0.0000	1.0000	0.0000	0.0000	0.0000
34	0.0000	0.0000	1.0000	0.0000	0.0000
35	0.0000	0.0000	1.0000	0.0000	0.0000
36	0.0000	0.0000	0.0000	1.0000	0.0000
37	0.0000	1.0000	0.0000	0.0000	0.0000
38	0.0000	0.0000	0.0000	1.0000	0.0000
39	0.0000	1.0000	0.0000	0.0000	0.0000
40	0.0000	1.0000	0.0000	0.0000	0.0000
41	0.0000	0.0000	0.0000	1.0000	0.0000
42	0.0000	0.0000	0.0000	1.0000	0.0000
43	0.0000	0.0000	1.0000	0.0000	0.0000

Summarized Data for Schedule Risk Magnitudes Rated by Respondents (Cont)

44	0.0000	1.0000	0.0000	0.0000	0.0000
45	0.0000	0.0000	1.0000	0.0000	0.0000
46	0.0000	1.0000	0.0000	0.0000	0.0000
47	0.0000	0.0000	1.0000	0.0000	0.0000
48	0.0000	1.0000	0.0000	0.0000	0.0000
49	1.0000	0.0000	0.0000	0.0000	0.0000
50	0.0000	1.0000	0.0000	0.0000	0.0000
51	0.0000	1.0000	0.0000	0.0000	0.0000
52	1.0000	0.0000	0.0000	0.0000	0.0000
53	0.0000	0.0000	1.0000	0.0000	0.0000

Appendix M: Ranked Data for Schedule Risk Drivers

Case	One	Two	Three	Four	Five	Six	Seven	Eight	Nine
1	6	5	7	4		1	3	2	
2	1			2	3	4			
3	3	4	5		1	2		5	
4	8	6	3	7	5	4	2	1	
5			3		2		1		
6		6	5		3	2	4	1	
7	5	6	7	3	4	2	8	1	
8		3	2		4			1	
9			1		2	4	3		
10	3	5	7	4	6	1	8	2	
11	3	1	3	1	2	2		1	
12	7	5	4	8	1	6	2	3	
13	1	5	4	2	6	7	8	3	
14		1	2	4	3				
15	1	2	2	2	3	3	2	2	
16	2	1	3	3	2	2	2	1	
17	5		1	6		2	3	4	
18	8	7	3	5	2	4	6	1	
19	3		1			2	3	3	
20		1			2			3	
21	1	1	5	2	3	4	5	3	
22	1	1	1	1	2	2	3	2	1
23	7	5	4	8	1	6	2	3	
24	3	2	1			4			
25	1		2				4	3	
26	2					3	1		
27			2				1		1
28									
29	1	2	2	3	2	2	1	3	
30		4	3		2		1		
31	2		3		4			1	
32	3		4		2		1	5	
33			2				1		
34	2		3			4		1	
35	3	4	7	8	5	1	2	6	
36									
37	3						1	2	
38									
39					1			2	
40	1	3	3	3	3	3	2	2	
41									
42									
43	1		2				3	3	

Ranked Data for Schedule Risk Drivers (Cont)

44	2			1		3		
45	1	3	1	2	3	2	3	1
46	3	2	1	3	3	1	3	1
47	1						2	
48	1		2		3			
49	1						3	5
50	1	4	7	3	2	6	8	5
51	1		2		3			
52	1						2	3
53	1						2	

Appendix N: Ranked Data for Schedule Risk Drivers after Ties

Case	One	Two	Three	Four	Five	Six	Seven	Eight	Nine
1	6	5	7	4	8.5	1	3	2	8.5
2	1	7	7	2	3	4	7	7	7
3	3	4	5.5	8	1	2	8	5.5	8
4	8	6	3	7	5	4	2	1	9
5	6.5	6.5	3	6.5	2	6.5	1	6.5	6.5
6	8	6	5	8	3	2	4	1	8
7	5	6	7	3	4	2	8	1	9
8	7	3	2	7	4	7	7	1	7
9	7	7	1	7	2	4	3	7	7
10	3	5	7	4	6	1	8	2	9
11	6.5	2	6.5	2	4.5	4.5	8.5	2	8.5
12	7	5	4	8	1	6	2	3	9
13	1	5	4	2	6	7	8	3	9
14	7	1	2	4	3	7	7	7	7
15	1	4	4	4	7.5	7.5	4	4	9
16	4	1.5	6.5	6.5	8	4	4	1.5	9
17	5	8	1	6	8	2	3	4	8
18	8	7	3	5	2	4	6	1	9
19	4	7.5	1	7.5	7.5	2	4	4	7.5
20	6.5	1	6.5	6.5	2	6.5	6.5	3	6.5
21	1.5	1.5	6.5	3	4.5	8	6.5	4.5	9
22	3	3	3	3	7	7	9	7	3
23	7	5	4	8	1	6	2	3	9
24	3	2	1	7	7	4	7	7	7
25	1	7	2	7	7	7	4	3	7
26	2	6.5	6.5	6.5	6.5	3	1	6.5	6.5
27	6.5	6.5	3	6.5	6.5	6.5	1.5	6.5	1.5
28	1.5	4.5	4.5	7.5	4.5	4.5	1.5	7.5	9
29	7	4	3	7	2	7	1	7	7
30	2	7	3	7	4	7	7	1	7
31	3	7.5	4	7.5	2	7.5	1	5	7.5
32	6	6	2	6	6	6	1	6	6
33	2	7	3	7	7	4	7	1	7
34	3	4	7	8	5	1	2	6	9
35	3	6.5	6.5	6.5	6.5	6.5	1	2	6.5
36	6	6	6	6	1	6	6	2	6
37	1	6	6	6	6	6	2.5	2.5	9
38	1	7	2	7	7	7	3.5	3.5	7
39	2	6.5	6.5	1	6.5	3	6.5	6.5	6.5
40	2	7	2	4.5	7	4.5	7	2	9
41	6.5	4	2	6.5	6.5	2	6.5	2	9
42	1	6	6	6	6	6	2	6	6
43	1	6.5	2	6.5	3	6.5	6.5	6.5	6.5

Ranked Data for Schedule Risk Drivers after Ties (Cont)

44	1	6.5	6.5	6.5	6.5	6.5	2	3	6.5
45	1	4	7	3	2	6	8	5	9
46	1	6.5	2	6.5	3	6.5	6.5	6.5	6.5
47	1	6.5	6.5	6.5	6.5	6.5	2	3	6.5
48	1	6	6	6	6	6	2	6	6

Appendix O: Summarized Data for Management Risk Magnitudes Rated by Respondents

CASE	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW
1	1.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000	0.0000	0.0000
3	0.0000	1.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	1.0000	0.0000	0.0000
5	0.0000	1.0000	0.0000	0.0000	0.0000
6	0.0000	1.0000	0.0000	0.0000	0.0000
7	1.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	1.0000	0.0000	0.0000	0.0000
9	0.0000	1.0000	0.0000	0.0000	0.0000
10	0.0000	1.0000	0.0000	0.0000	0.0000
11	1.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	1.0000	0.0000	0.0000
13	1.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	1.0000	0.0000	0.0000	0.0000
15	0.0000	1.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	1.0000	0.0000	0.0000
17	0.0000	1.0000	0.0000	0.0000	0.0000
18	1.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	1.0000	0.0000	0.0000	0.0000
20	0.0000	1.0000	0.0000	0.0000	0.0000
21	0.0000	1.0000	0.0000	0.0000	0.0000
22	0.0000	1.0000	0.0000	0.0000	0.0000
23	0.0000	0.0000	1.0000	0.0000	0.0000
24	0.0000	0.0000	1.0000	0.0000	0.0000
25	0.0000	0.0000	1.0000	0.0000	0.0000
26	0.0000	1.0000	0.0000	0.0000	0.0000
27	0.0000	0.0000	1.0000	0.0000	0.0000
28	0.0000	0.0000	1.0000	0.0000	0.0000
29	0.0000	0.0000	1.0000	0.0000	0.0000
30	0.0000	0.0000	1.0000	0.0000	0.0000
31	0.0000	1.0000	0.0000	0.0000	0.0000
32	0.0000	0.0000	1.0000	0.0000	0.0000
33	0.0000	0.0000	1.0000	0.0000	0.0000
34	0.0000	0.0000	1.0000	0.0000	0.0000
35	0.0000	0.0000	1.0000	0.0000	0.0000
36	0.0000	0.0000	0.0000	1.0000	0.0000
37	0.0000	0.0000	1.0000	0.0000	0.0000
38	0.0000	0.0000	0.0000	1.0000	0.0000
39	0.0000	1.0000	0.0000	0.0000	0.0000
40	0.0000	0.0000	1.0000	0.0000	0.0000
41	0.0000	0.0000	1.0000	0.0000	0.0000
42	0.0000	0.0000	0.0000	1.0000	0.0000
43	0.0000	0.0000	1.0000	0.0000	0.0000

Summarized Data for Management Risk Magnitudes Rated by Respondents (Cont)

44	0.0000	0.0000	1.0000	0.0000	0.0000
45	0.0000	1.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	1.0000	0.0000	0.0000
47	0.0000	1.0000	0.0000	0.0000	0.0000
48	0.0000	0.0000	0.0000	1.0000	0.0000
49	0.0000	0.0000	1.0000	0.0000	0.0000
50	0.0000	0.0000	1.0000	0.0000	0.0000
51	0.0000	0.0000	1.0000	0.0000	0.0000
52	0.0000	0.0000	1.0000	0.0000	0.0000
53	0.0000	0.0000	1.0000	0.0000	0.0000
54	0.0000	0.0000	1.0000	0.0000	0.0000

Appendix P: Ranked Data for Management Risk Drivers

Case	One	Two	Three	Four	Five	Six	Seven	Eight
1	5	4	3		6	1	2	
2		2	1		3		4	
3	1	2	5		3	4		
4	5	1	6	3	2	4	7	
5			2		1	4	3	
6			2	3		1		4
7	6	1	5	7	2	3	4	
8	3		2		1	5	4	
9		2	3		1			
10	1	6	3	7	2	4	5	
11		1	2		1	1	3	
12	2	1	5		4	3		
13	1	2	7	6	5	3	4	
14			2		3	1	4	
15	1	2	2	1	1	2	1	
16	1	1	1	2	2	1	1	
17	5	1			2	3	4	
18	4	1	5	7	6	2	3	
19		1			2	2		
20		1			2		3	
21	3	1	2	4	3	5	6	
22	3	2	1	3	1	1	1	
23	2	1	5	6	4	3	7	
24								
25			2		3	1		
26	2			3	1	4		
27					3			1
28	3	2			1			
29	1	1	1	3	1	2	3	
30	3	2			1			
31	5	4		1		3	2	
32	2				1			
33	1	3			2			
34	5	1	7	4	2	6	3	
35	4	1	7	3	2	5	6	
36								
37	5	4	3	2	1	6	7	
38								
39					2	1		
40			1		2	3		
41	1	3	3	3	2	3	3	
42								
43	2			3	1			

Ranked Data for Management Risk Drivers (Cont)

44	1	2		3	2		
45			1			2	3
46	3	2	2	1	2	1	2
47	2	2	2	2	1	1	2
48							
49	1						2
50	3	1	4		2	5	
51	1	2	3	6	4	7	5
52	1						2
53	3	1	4		2	5	
54	1				2		

Appendix Q: Ranked Data for Management Risk Drivers after Ties

Case	One	Two	Three	Four	Five	Six	Seven	Eight
1	5	4	3	7.5	6	1	2	7.5
2	6.5	2	1	6.5	3	6.5	4	6.5
3	1	2	5	7	3	4	7	7
4	5	1	6	3	2	4	7	8
5	6.5	6.5	2	6.5	1	4	3	6.5
6	6.5	6.5	2	3	6.5	1	6.5	4
7	6	1	5	7	2	3	4	8
8	3	7	2	7	1	5	4	7
9	6	2	3	6	1	6	6	6
10	1	6	3	7	2	4	5	8
11	7	2	4	7	2	2	5	7
12	2	1	5	7	4	3	7	7
13	1	2	7	6	5	3	4	8
14	6.5	6.5	2	6.5	3	1	4	6.5
15	2.5	6	6	2.5	2.5	6	2.5	8
16	3	3	3	6.5	6.5	3	3	8
17	5	1	7	7	2	3	4	7
18	4	1	5	7	6	2	3	8
19	6	1	6	6	2.5	2.5	6	6
20	6	1	6	6	2	6	3	6
21	3.5	1	2	5	3.5	6	7	8
22	6.5	5	2.5	6.5	2.5	2.5	2.5	8
23	2	1	5	6	4	3	7	8
24	6	6	2	6	3	1	6	6
25	2	6.5	6.5	3	1	4	6.5	6.5
26	5.5	5.5	5.5	5.5	2	5.5	5.5	1
27	3	2	6	6	1	6	6	6
28	2.5	2.5	2.5	6.5	2.5	5	6.5	8
29	3	2	6	6	1	6	6	6
30	5	4	7	1	7	3	2	7
31	2	5.5	5.5	5.5	1	5.5	5.5	5.5
32	1	3	6	6	2	6	6	6
33	5	1	7	4	2	6	3	8
34	4	1	7	3	2	5	6	8
35	5	4	3	2	1	6	7	8
36	5.5	5.5	5.5	5.5	2	1	5.5	5.5
37	6	6	1	6	2	3	6	6
38	1	5	5	5	2	5	5	8
39	2	6	6	3	1	6	6	6
40	1	2.5	6.5	4	2.5	6.5	6.5	6.5
41	6	6	1	6	6	2	3	6
42	7	4.5	4.5	1.5	4.5	1.5	4.5	8
43	5	5	5	5	1.5	1.5	5	8

Ranked Data for Management Risk Drivers after Ties (Cont)

44	1	5.5	5.5	5.5	5.5	5.5	2	5.5
45	3	1	4	7	2	5	7	7
46	1	2	3	6	4	7	5	8
47	1	5.5	5.5	5.5	5.5	5.5	2	5.5
48	3	1	4	7	2	5	7	7
49	1	5.5	5.5	5.5	2	5.5	5.5	5.5

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Vita

Te-lung Tsai was born on 25 July 1954 in Miaoli, Taiwan, the Republic of China. After graduating from junior high school in 1970, he attended the Chinese Air Force Preparatory School (CAFPS). Upon completing three years of study at CAFPS, he subsequently enrolled in the Chinese Air Force Academy (CAFA) in 1973 where he studied and received flight training. He graduated from the CAFA in 1977 and was commissioned in the same year.

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In 1981, he attended the Fighter Weapons Instructor Course at Williams AFB, Arizona, USA. He was subsequently assigned as a Weaponry Instructor Pilot at several Chinese Air Force bases. In 1988, he transferred to the ROCAF General Headquarters and served as Section Head of Program Control for the Indigenous Defense Fighter Program Management Office in Taipei.

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This research examined the magnitudes of the performance, supportability, life-cycle cost, schedule, and management risk factors in current Republic of China Air Force (ROCAF) weapon systems acquisition programs and analyzed the risk drivers with respect to those risk factors.

Mid-to-high level managers in the ROCAF and Chung-Sun Institute of Science and Technology (CSIST) were surveyed to determine the extent to which various risk factors were contributing to program risk. A total of fifty-four (54) managers responded to the survey. The results indicate: high risks to performance, supportability, life cycle cost, and schedule, and moderate risk to management. Risk-drivers that contributed to particular risk factors were also identified in which two major risk-drivers causing high risk to more than one risk factor; these are: first, ambiguous requirements or frequent requirements changes drive performance, cost, and schedule risks; second, tight program schedule caused by the need for rapid system deployment contributes to performance and supportability risks. Finally, recommendations for future research such as an overall considerations for acceptable risk in ROCAF acquisition process were also made.

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